DOWNLOAD PDF SUPERSYMMETRY IN PARTICLE PHYSICS

Chapter 1 : Supersymmetry and the Crisis in Physics - Scientific American

Supersymmetry is an extension of the Standard Model that aims to fill some of the gaps. It predicts a partner particle for each particle in the Standard Model. These new particles would solve a major problem with the Standard Model - fixing the mass of the Higgs boson.

There are representations of a Lie superalgebra that are analogous to representations of a Lie algebra. Each Lie algebra has an associated Lie group and a Lie superalgebra can sometimes be extended into representations of a Lie supergroup. The Supersymmetric Standard Model[edit] Main article: Minimal Supersymmetric Standard Model Incorporating supersymmetry into the Standard Model requires doubling the number of particles since there is no way that any of the particles in the Standard Model can be superpartners of each other. With the addition of new particles, there are many possible new interactions. The simplest possible supersymmetric model consistent with the Standard Model is the Minimal Supersymmetric Standard Model MSSM which can include the necessary additional new particles that are able to be superpartners of those in the Standard Model. Cancellation of the Higgs boson quadratic mass renormalization between fermionic top quark loop and scalar stop squark tadpole Feynman diagrams in a supersymmetric extension of the Standard Model One of the main motivations for SUSY comes from the quadratically divergent contributions to the Higgs mass squared. The quantum mechanical interactions of the Higgs boson causes a large renormalization of the Higgs mass and unless there is an accidental cancellation, the natural size of the Higgs mass is the greatest scale possible. This problem is known as the hierarchy problem. Supersymmetry reduces the size of the quantum corrections by having automatic cancellations between fermionic and bosonic Higgs interactions. If supersymmetry is restored at the weak scale, then the Higgs mass is related to supersymmetry breaking which can be induced from small non-perturbative effects explaining the vastly different scales in the weak interactions and gravitational interactions. In many supersymmetric Standard Models there is a heavy stable particle such as neutralino which could serve as a weakly interacting massive particle WIMP dark matter candidate. The existence of a supersymmetric dark matter candidate is related closely to R-parity. The standard paradigm for incorporating supersymmetry into a realistic theory is to have the underlying dynamics of the theory be supersymmetric, but the ground state of the theory does not respect the symmetry and supersymmetry is broken spontaneously. The supersymmetry break can not be done permanently by the particles of the MSSM as they currently appear. This means that there is a new sector of the theory that is responsible for the breaking. The only constraint on this new sector is that it must break supersymmetry permanently and must give superparticles TeV scale masses. There are many models that can do this and most of their details do not matter. In order to parameterize the relevant features of supersymmetry breaking, arbitrary soft SUSY breaking terms are added to the theory which temporarily break SUSY explicitly but could never arise from a complete theory of supersymmetry breaking. The renormalization group evolution of the three gauge coupling constants of the Standard Model is somewhat sensitive to the present particle content of the theory. These coupling constants do not quite meet together at a common energy scale if we run the renormalization group using the Standard Model. Supersymmetric quantum mechanics Supersymmetric quantum mechanics adds the SUSY superalgebra to quantum mechanics as opposed to quantum field theory. Supersymmetric quantum mechanics often becomes relevant when studying the dynamics of supersymmetric solitons , and due to the simplified nature of having fields which are only functions of time rather than space-time , a great deal of progress has been made in this subject and it is now studied in its own right. SUSY quantum mechanics involves pairs of Hamiltonians which share a particular mathematical relationship, which are called partner Hamiltonians. The potential energy terms which occur in the Hamiltonians are then known as partner potentials. An introductory theorem shows that for every eigenstate of one Hamiltonian, its partner Hamiltonian has a corresponding eigenstate with the same energy. This fact can be exploited to deduce many properties of the eigenstate spectrum. It is analogous to the original description of SUSY, which referred to bosons and fermions. We can imagine a "bosonic Hamiltonian", whose eigenstates are the various bosons of our theory. Each boson would have a fermionic partner of equal energy. Additionally, SUSY has been applied to disorder averaged systems both quantum and non-quantum through statistical mechanics , the Fokker-Planck equation being an example of a non-quantum theory. For more on the applications of supersymmetry in condensed matter physics see the book [30] Supersymmetry in optics[edit] Integrated optics was recently found [31] to provide a fertile ground on which certain ramifications of SUSY can be explored in readily-accessible laboratory settings. In this manner, a new class of functional optical structures with possible applications in phase matching , mode conversion [32] and space-division multiplexing becomes possible. SUSY transformations have been also proposed as a way to address inverse scattering problems in optics and as a one-dimensional transformation optics [33] Supersymmetry in dynamical systems[edit] Main article: Supersymmetric theory of stochastic dynamics All stochastic partial differential equations, the models for all types of continuous time dynamical systems, possess topological supersymmetry. The topological sector of the so-emerging supersymmetric theory of stochastic dynamics can be recognized as the Witten-type topological field theory. The meaning of the topological supersymmetry in dynamical systems is the preservation of the phase space continuityâ€”infinitely close points will remain close during continuous time evolution even in the presence of noise. When the topological supersymmetry is broken spontaneously, this property is violated in the limit of the infinitely long temporal evolution and the model can be said to exhibit the stochastic generalization of the butterfly effect. From a more general perspective, spontaneous breakdown of the topological supersymmetry is the theoretical essence of the ubiquitous dynamical phenomenon variously known as chaos , turbulence , self-organized criticality etc. Supersymmetry in mathematics[edit] SUSY is also sometimes studied mathematically for its intrinsic properties. This is because it describes complex fields satisfying a property known as holomorphy , which allows holomorphic quantities to be exactly computed. This makes supersymmetric models useful " toy models " of more realistic theories. A prime example of this has been the demonstration of S-duality in four-dimensional gauge theories [36] that interchanges particles and monopoles. The proof of the Atiyah-Singer index theorem is much simplified by the use of supersymmetric quantum mechanics. Supersymmetry in quantum gravity[edit].

Chapter 2 : Breaking supersymmetry

Supersymmetry represents the culmination of the search for fundamental symmetries that has dominated particle physics for 50 years. Traditionally, the constituents of matter (fermions) were regarded as different from the particles (bosons) transmitting the forces between them. In supersymmetry, fermions and bosons are unified.

Supersymmetry is an extension of the Standard Model that aims to fill some of the gaps. It predicts a partner particle for each particle in the Standard Model. These new particles would solve a major problem with the Standard Model â€” fixing the mass of the Higgs boson. If the theory is correct, supersymmetric particles should appear in collisions at the LHC. At first sight, the Standard Model seems to predict that all particles should be massless, an idea at odds with what we observe around us. Theorists have come up with a mechanism to give particles masses that requires the existence of a new particle, the Higgs boson. However, it is a puzzle why the Higgs boson should be light, as interactions between it and Standard-Model particles would tend to make it very heavy. The extra particles predicted by supersymmetry would cancel out the contributions to the Higgs mass from their Standard-Model partners, making a light Higgs boson possible. The new particles would interact through the same forces as Standard-Model particles, but they would have different masses. If supersymmetric particles were included in the Standard Model, the interactions of its three forces â€” electromagnetism and the strong and weak nuclear forces â€” could have the exact same strength at very high energies, as in the early universe. A theory that unites the forces mathematically is called a grand unified theory, a dream of physicists including Einstein. Supersymmetry would also link the two different classes of particles known as fermions and bosons. Particles like those in the Standard Model are classified as fermions or bosons based on a property known as spin. Fermions all have half of a unit of spin, while the bosons have 0, 1 or 2 units of spin. Supersymmetry predicts that each of the particles in the Standard Model has a partner with a spin that differs by half of a unit. So bosons are accompanied by fermions and vice versa. Linked to their differences in spin are differences in their collective properties. Fermions are very standoffish; every one must be in a different state. On the other hand, bosons are very clannish; they prefer to be in the same state. Fermions and bosons seem as different as could be, yet supersymmetry brings the two types together. Finally, in many theories scientists predict the lightest supersymmetric particle to be stable and electrically neutral and to interact weakly with the particles of the Standard Model. These are exactly the characteristics required for dark matter, thought to make up most of the matter in the universe and to hold galaxies together. The Standard Model alone does not provide an explanation for dark matter. Perhaps the reason we still have some of these questions about the inner workings of the universe is because we have so far only seen half of the picture.

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Chapter 3 : Supersymmetry Fails Test, Forcing Physics to Seek New Ideas - Scientific American

In particle physics, supersymmetry (SUSY) is a principle that proposes a relationship between two basic classes of elementary particles: bosons, which have an integer-valued spin, and fermions, which have a half-integer spin.

The first run of the LHC at 7 TeV culminated with the successful detection of what is widely believed to be the Higgs boson , a particle thought to explain how other particles get their mass. The discovery completed the Standard Model of particle physics and earned the two scientists who worked on the theory the Nobel Prize. But the collider has so far failed to produce any evidence of supersymmetry. Also known as SUSY, it is one of the leading theories physicists have put forward as an extension of the Standard Model of physics. Such an extension is needed to explain the remaining mysteries in the universe that the Standard Model does not account for, such as the nature of dark matter, the invisible stuff that is thought to make up most of the matter in the universe. So far, it has not been possible to observe it directly. Over time, these particles disappeared, decaying into dark-matter particles and so-called ordinary particles, such as quarks and leptons. When protons collide with each other at near the speed of light, as they do inside the LHC, they can produce new, exotic particles alongside known particles. Dark Matter Throughout the Universe] If sparticles exist, they are expected to appear as jets of hadrons â€" composite particles made of quarks â€" streaming out of proton-proton collisions. The momentum of these jets would not be balanced. This missing momentum would be a signal of a supersymmetric neutralino particle, a hypothetical particle that is the leading candidate for dark matter. The neutralino "acts like a thief, stealing away momentum without leaving any trace in the detector," said Allanach. Data loopholes So far, neither the neutralino nor any other supersymmetric particle has been found. But Allanach said that to net them, researchers need to account for a loophole in the way they read the collision data. This loophole is the existence of so-called multiple solutions, or several ways to interpret the results of proton-proton collisions. But there could be another solution â€" one where the particles would have a slightly different mass, and they would then decay in slightly different ways. In that case, "the pattern of the collision in the LHC could actually be different," said Allanach. Even so, Allanach remains hopeful. So we should wait and see what happens at least with the next run of the LHC. In that case, new colliders with even higher energies should be built, for collisions at energies as high as TeV.

Chapter 4 : Supersymmetry - Wikipedia

Supersymmetry in Particle Physics: An Elementary Introduction - Kindle edition by Ian Aitchison. Download it once and read it on your Kindle device, PC, phones or tablets. Use features like bookmarks, note taking and highlighting while reading Supersymmetry in Particle Physics: An Elementary Introduction.

From Simons Science News As a young theorist in Moscow in , Mikhail Shifman became enthralled with an elegant new theory called supersymmetry that attempted to incorporate the known elementary particles into a more complete inventory of the universe. Over the decades, he and thousands of other physicists developed the supersymmetry hypothesis, confident that experiments would confirm it. In an essay posted last month on the physics website arXiv. So far, no hints of "new physics" beyond the Standard Model â€” the accepted set of equations describing the known elementary particles â€” have shown up in experiments at the Large Hadron Collider, operated by the European research laboratory CERN outside Geneva, or anywhere else. The recently discovered Higgs boson was predicted by the Standard Model. In the absence of some guidance from experimental data, how do you guess something about nature? In a blog post about the recent experimental results, Falkowski joked that it was time to start applying for jobs in neuroscience. The theory is alluring for three primary reasons: It predicts the existence of particles that could constitute "dark matter," an invisible substance that permeates the outskirts of galaxies. It unifies three of the fundamental forces at high energies. And â€” by far the biggest motivation for studying supersymmetry â€” it solves a conundrum in physics known as the hierarchy problem. The particles that carry the weak force, called W and Z bosons, derive their masses from the Higgs field, a field of energy saturating all space. Because other particles are intertwined with the Higgs field, their energies should spill into it during events known as quantum fluctuations. This should quickly drive up the energy of the Higgs field, making the W and Z bosons much more massive and rendering the weak nuclear force about as weak as gravity. According to the theory, fermions, which constitute matter, have superpartners that are bosons, which convey forces, and existing bosons have fermion superpartners. Because particles and their superpartners are of opposite types, their energy contributions to the Higgs field have opposite signs: One dials its energy up, the other dials it down. As a bonus, one of the undiscovered superpartners could make up dark matter. Over time, as the superpartners failed to materialize, supersymmetry has grown less beautiful. According to mainstream models, to evade detection, superpartner particles would have to be much heavier than their twins, replacing an exact symmetry with something like a carnival mirror. Physicists have put forward a vast range of ideas for how the symmetry might have broken, spawning myriad versions of supersymmetry. But the breaking of supersymmetry can pose a new problem. Most particle physicists in the s thought they would detect superpartners that are only slightly heavier than the known particles. But the Tevatron, the now-retired particle accelerator at Fermilab in Batavia, Ill. As the Large Hadron Collider probes increasingly higher energies without any sign of supersymmetry particles, some physicists are saying the theory is dead. Today, most of the remaining viable versions of supersymmetry predict superpartners so heavy that they would overpower the effects of their much lighter twins if not for fine-tuned cancellations between the various superpartners. But introducing fine-tuning in order to scale back the damage and solve the hierarchy problem makes some physicists uncomfortable. In others, the superpartners are not heavier than existing particles but merely less stable, making them more difficult to detect. These theories will continue to be tested at the Large Hadron Collider after it is upgraded to full operational power in about two years. And, without an even higher-energy collider to test alternative ideas, Falkowski says, the field will undergo a slow decay: That happens in a wonderfully internal way. People continue to work on what they find fascinating, and science meanders toward truth.

Chapter 5 : Introduction to Supersymmetry

The standard model of particle physics, which describes every particle we know of and how they interact, was given much credence when the Higgs boson was discovered in Now, measurements of a.

It is thought to dominate the mass of the universe and the evidence is very hard to refute. Probably the best candidate for an explanation is an idea known as supersymmetry. Physicists like to exploit symmetry to build their theories. For example, that it does not matter if I perform an experiment today or next week all things being equal constitutes a statement of symmetry and, impressively enough, it leads directly to the law of energy conservation. Supersymmetry is harder to visualise but its implications are not. It demands that for every type of elementary particle there should be a would-be twin. This means that the mere existence of electrons implies that supersymmetric electrons should also exist they are called "selectrons". I said "would-be twin" because if supersymmetry were a perfect symmetry, the electron and the selectron would have the same mass, but experiments over many years have established that this is not the case. The upshot is that if supersymmetry is realised in nature then it must also be "broken" to some degree, with the result that the super-particles should all be heavier than the twins we have already seen. This does sound contrived; we have introduced a symmetry and then found we need to break it to hide the embarrassing extra particles that it predicts. But broken symmetry is the norm and often occurs when systems cool down. For example, at high enough temperatures, water molecules are free to move around in all directions, but as the air cools they freeze together and produce those beautiful patterns we see on an icy cold window pane. In this case, the "all directions" symmetry is broken to the diminished symmetry embodied in the pattern on the window. So it is to be expected that supersymmetry is not readily apparent in the relative coldness of our experiments. As a bonus, the fact that all those super-particles should be heavy compared to the common-or-garden particles produced daily at Cern turns out to be a direct consequence of broken symmetry â€” and so supersymmetry is not so contrived after all. The fact that one of those super-particles has all the characteristics needed of dark matter is an attractive bonus. Supersymmetry was not invented to explain dark matter. It sits alongside curved spacetime as one of those beautiful ideas that seem simply too good not to be true. This unification is an essential ingredient of theories such as string theory. For many theoretical physicists, it is hard to believe that supersymmetry does not play a role somewhere in nature. The big question is whether its influence is confined only to the very earliest moments of the universe; moments that lie outside of the reach even of the Large Hadron Collider LHC. We are encouraged to suppose that this is not the case and that super-particles might show up soon not only because that is what the dark matter explanation would suggest but because it also provides an explanation for why the Higgs particle should be as light as it seems to be. So what of the evidence? Prior to the LHC turning on, there was no shortage of optimism that super-particles might be produced in abundance and that we would be celebrating their discovery by now, but that has not proved to be the case. The latest news in the search for supersymmetry was presented at the recent Hadron Collider symposium in Kyoto from which the BBC reported a result presented by the LHC Beauty collaboration LHCb for short as representing a "significant blow" to supersymmetry. So what did they measure and what does it imply? The rough-and-ready way to discover supersymmetry at the LHC is to smash protons into each other and scan the debris for traces that a super-particle was produced. But there is another way to tease out supersymmetry: Super-particles ought to have an impact on quantities that the LHCb experimenters are measuring even though they might actually be too heavy to be produced. In that moment, it is possible to create a super-particle. The trace that this has happened is usually too small to measure, a tiny ripple in an ocean of waves. But this is where the LHCb comes in. The experimenters have been studying the fate of the beauty meson or B-meson for short. B-mesons are produced prolifically and the LHCb experiment is set up to study them with high precision. However, there are very rare cases where the mesons do not decay in the usual way. One case was predicted to be so rare as to be almost disallowed by established physics. This is when the meson decays and, in its death throes, produces a pair of muons a heavy version of the electron. This should occur around three times for every billion mesons produced. This extreme rarity means there is an opportunity for the tiny super-particle effect to manifest itself in a measurable way â€” it is like the ocean waves have been stilled, making the ripples easier to spot. All that is needed is for the experimenters to identify the decay and count how often it happens. If it happens too often or too infrequently , then we can start to get excited. The bottom line is that the experimenters have made the measurement â€” they have counted those thrice-in-a-billion decays and found perfect agreement with the standard theory, with no trace of any super-particles or any other new particles for that matter. So where does that leave supersymmetry? The LHCb measurement, combined with other measurements from the LHC, helps to cut down the possibilities but the data remain very far from ruling out supersymmetry. Until the LHC turned on, there was much theoretical speculation and this is being whittled down. This is what the LHC was built to do and it will either discover supersymmetry and confirm its prediction for dark matter or it will exclude it to the point whereby many of its attractive features are lost. Supersymmetry is too broad an idea to be entirely excluded by the LHC, but its specific instances are progressively falling by the wayside. As ever in science, we need to be patient.

Chapter 6 : Supersymmetryâ€™s absence at LHC puzzles physicists | Science News

Supersymmetry, in particle physics, a symmetry between fermions (subatomic particles with half-integer values of intrinsic angular momentum, or spin) and bosons (particles with integer values of spin).

Supersymmetry is a conjectured symmetry of space and time â€” and a unique one. It has been a very popular idea among theoretical physicists, for a number of reasons, for several decades â€” it was a hit back when I was a student, before physics was cool, and even well before. An automatic consequence of having this symmetry in nature is that every type of particle has one or more superpartners â€” other types of particles that share many of the same properties, but differ in a crucial way. If a particle is a fermion, its super-partner is a boson. If a particle is a boson, its super-partner is a fermion. What are fermions and bosons? Click here to find out! Our world has many fermions â€” all the matter particles â€” and many bosons â€” all the force carriers. But none of them have the right properties to be super-partners of one other. So therefore, if supersymmetry were a symmetry of nature, every type of elementary particle that we know of in nature would have to have partners we have not discovered yet. Since there are over two dozen particles known, that would mean we have a lot of work left to do! What is this symmetry, really? In a bosonic dimension â€” the ones we are used to â€” you can move as far as you want, taking step after step to the left, say. Moving in a fermionic dimension, it is as though you can only take one step. The only thing you can do is go back. Ok, that sounds really weird, and it is; in the end, you have to define that kind of dimension using math, not words or analogies. His theory consists of a set of equations that obey a certain set of symmetries. So supersymmetry is, in this sense, very special. Where are those superpartner particles? Were supersymmetry an exact symmetry of nature, we would already have found many superpartners. If the world were exactly supersymmetric, every particle known would have superpartners with the same interactions and the same mass. But fermions have boson superpartners, and vice versa. For each matter fermion, such as the electron or the strange quark, you see that there are two new particlesâ€¦ both bosons. They have rather ugly names, I am afraid, such as selectron and strange squark, the s prefix standing for supersymmetry. You might wonder why there are two and why there is only one for each neutrino. Take a look at Fig. For the force carrier bosons, they instead have a partner fermion. The photon has a photino, the gluons have gluinos, etc. The massive W bosons are a little more confusing. All of these particles have exactly the same mass, in this imaginary exactly-supersymmetric world. There are two Higgs particles h0 and H0 in this model, and each has a partner Higgsino. One is massless and the other has a mass. Turns out that in a supersymmetric world you need two to allow both the up-type quarks and the down-type quarks to get their masses in the usual way. Another argument is that you need two higgsinos to avoid mathematical inconsistency. But this exactly supersymmetric world is obviously not our world. For one thing, we would have atoms with electrons in them, and atoms with selectrons in them, and atoms with both. Data and daily life completely exclude this possibility. There are no selectrons with the mass of the electron, period. So exact supersymmetry is not a correct theory of nature, and we knew that before supersymmetry was first thought of. Despite this seeming disaster, the original theoretical proposal of supersymmetry allows a very simple and even plausible way out. It is a common notion in physics that symmetries may be hidden from view physicists often say spontaneously broken, but really this is not a good image to have intuitively â€” the symmetry is still there, it has just been made difficult to recognize. The laws of physics are rotationally symmetric, as the hair on your head would indicate were you floating far from any massive objects like the earth or sun. But on earth, the rotational symmetry is hidden; right-side up, up-side down and sideways take on meaning. One example involves rotational symmetry on the earth. The laws of nature are the same no matter how you rotate your experiment see Fig. This is true, but hard to recognize on earth, where it does matter whether your experiment is right-side-up, up-side-down, or tilted sideways. But far out in space, far away from all the planets, moons and stars, the laws of nature are rotationally symmetric. Your experiment will give the same answer no matter how you orient it. Incidentally, measurements of light emitted from very distant atoms do indeed confirm this. What the earth does is confuse us. It makes us think that down is a very different direction from up or from left. But that apparent difference is not intrinsic to the laws of nature. The difference arises because the earth is nearby, hiding rotational symmetry from our view. What would happen then? It turns out that it is quite easy to get a world that looks just like ours, in which the superpartners of the known particles exist but have become heavyâ€¦ too heavy for us yet to have produced them in experiments. For supersymmetry to be consistent with data, it must be hidden or "spontaneously broken". To reduce clutter, I have removed the lines that were present in Figure 1, which indicated which particles interact directly. The basic interactions are not changed by supersymmetry breaking, and are still the same as shown in Figure 1. You see that supersymmetry breaking the hiding of the symmetry from easy view , whose details are not specified, has pushed all the superpartners up to a mass scale around or above the top quark mass. This is not as arbitrary or silly as it sounds â€" the mathematics readily accomodates this effect. There are many precise examples of how this could happenâ€¦ but far too many for us to guess which of them is most likely. There are many, many other possibilities, which I will refer to as different variants of supersymmetry. There are some good reasons for this popularity; it turns out there are a number of independent ways to get a pattern similar to this. However, popularity always introduces bias, and we should keep our minds open, not simply assuming these good reasons are correct. From what I have told you so far, yes, that would most definitely be a risk. What is the hierarchy problem? How does supersymmetry solve it? And what does the Large Hadron Collider data have to say, so far, about supersymmetry?

Chapter 7 : Supersymmetry: is it really too good not to be true? | Science | The Guardian

What is supersymmetry? Supersymmetry is a conjectured symmetry of space and time â€" and a unique one. It has been a very popular idea among theoretical physicists, for a number of reasons, for several decades â€" it was a hit back when I was a student, before physics was cool, and even well before.

Introduction to Supersymmetry 20th century physics has seen two major paradigm shifts in the way we understand Mother Nature. One is quantum mechanics, and the other is relativity. The marriage between the two, called quantum field theory, conceived an enfant terrible, namely anti-matter. As a result, the number of elementary particles doubled. The couple has not been getting along very well, resulting in mathematical inconsistencies, meaningless infinities, and negative probabilities. The key to success may be in supersymmetry, which doubles the number of particles once more. Why was anti-matter needed? One reason was to solve a crisis in the 19th century physics of classical electromagnetism. An electron is, to the best of our knowledge, a point particle. Namely, it has no size, yet an electric charge. A charged particle inevitably produces an electric potential around it, and it also feels the potential created by itself. This leads to an infinite "self-energy" of the electron. In other words, it takes substantial energy to "pack" all the charge of an electron into small size. For an electron, its rest energy is known to be 0. For this given amount of energy, it cannot afford to "pack" itself into a size smaller than the size of a nucleus. Classical theory of electromagnetism is not a consistent theory below this distance. However, it is known that the electron is at least ten thousand times smaller than that. In quantum mechanics, it is possible to "borrow" energy within the time interval allowed by the uncertainty principle. Once there exists anti-matter, which can annihilate matter or be created with matter, what we consider to be an empty vacuum undergoes a fluctuation to produce a pair of electron and positron together with photon, annihilating back to vacuum within the time interval allowed by the uncertainty principle a. In addition to the effect of the electric potential on itself b , the electron can annihilate with a positron in the fluctuation, leaving the electon originally in the fluctuation to materialize as a real electron c. It turns out, these two contributions to the energy of the electron almost nearly cancel with each other. The small size of the electron was made consistent with electromagnetism thanks to quantum mechanics and the existence of anti-matter. Currently the Standard Model of particle physics is facing a similar crisis. We know that our Universe is filled with a mysterious condensate of Higgs boson, which disturbs matter particles and forces, not letting them go far and hence making them massive. For example, the carrier of the weak force, W boson, bumps on the Higgs condensate all the time, and the force has become short-ranged, extending only over a thoughsandth of the size of nuclei. All masses of known elementary particles must have come from the Higgs boson. However, the mass of the Higgs boson receives a large contribution from its interaction with itself making it impossible for us to study physics at smaller distances. Because the gravity is believed to be unified with other forces at an extremely small distance called Planck length , the marriage between quantum mechanics and gravity appears a remote dream. Supersymmetry is an idea that history repeats itself to solve similar problems. By doubling the number of particles again, there is similar cancellation between the process with ordinary particles only and another process with their superpartners. Then the Standard Model can describe physics down to the Planck length, making the marriage a realistic hope. In fact, it is a necessary ingredient in the only available candidate for quantum theory of gravity, string theory. In a , in the Standard Model without supersymmetry, the strengths of three forces change as a function of energies, and become closer to each other at very high energies. Our galaxy is known to be full of Dark Matter, weakly interacting particles whose gravitational pull binds the galaxy together despite its fast rotation. The picture a shows the measurement of Doppler shift in 21cm line that allows us to determine the rotational speed of other galaxies. The rotational speed is much faster than what the gravitional pull by stars would allow b. One of the best candidates for Dark Matter is the lightest supersymmetric particle. Even though supersymmetry solves many problems in particle physics, it also poses new problems. What makes superpartners heavier than ordinary particles? This is the problem of supersymmetry breaking. Why are superpartners so well hidden in rare phenomena? Arbitrary mass spectrum of superpartners actually would cause too large effects in rare processes that change flavor of particles. There must be some special reason why such effects are well hidden. How do we discover superpartners experimentally? How do we extract information on the mechanism of supersymmetry breaking? How does supersymmetry impact cosmology? Is the lightest supersymmetric partner the Dark Matter? How do we prove it? We are working on these problems. Our group had made substantial contributions to the theoretical study of supersymmetry. It was Bruno Zumino , together with Julius Wess, who discovered the possibility of supersymmetry in four-dimensional spacetime back in Lawrence Hall , together with Joe Lykken and Steven Weinberg, laid the foundation of relatistic supersymmetric phenomenology. Mary K Gaillard made it possible to systematically study quantum effects in supersymmetric theory of gravity, supergravity. Hitoshi Murayama , together with Gian Giudice and two former Berkeley postdocs, Markus Luty and Riccardo Rattazzi, found subtle quantum contributions to masses of superpartners, independently with two other former Berkeley postdocs, Lisa Randall and Raman Sundrum. This home page is based on the introduction in Supersymmetry Phenomenology by Hitoshi Murayama. Phone , Campus phone Location Bldg.

Chapter 8 : New blow for 'supersymmetry' physics theory

According to supersymmetry, every existing particle in the Standard Model has a supersymmetric partner.

Chapter 9 : Minimal Supersymmetric Standard Model - Wikipedia

The Minimal Supersymmetric Standard Model (MSSM) is an extension to the Standard Model that realizes supersymmetry. MSSM is the minimal supersymmetrical model as it considers only "the [minimum] number of new particle states and new interactions consistent with phenomenology".