Quantum Physics Timeline

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1873 James Clerk Maxwell performs important research in three areas: color vision, molecular theory, and electromagnetic theory. The ideas underlying Maxwell's theories of electromagnetism describe the propagation of light waves in a vacuum.

1874 George Stoney develops a theory of the electron and estimates its mass.

1895 Wilhelm Röntgen discovers x rays.

1897 Pieter Zeeman shows that light is radiated by the motion of charged particles in an atom.

Joseph John (J.J.) Thomson discovers the electron.

1898 Marie and Pierre Curie separate radioactive elements.

J.J. Thompson measures the electron and puts forth his "plum-pudding" model of the atom -- that the atom is a slightly positive sphere with small, raisin-like negative electrons inside.

1900 Max Planck, to explain black body radiation (1862), which could not be explained in terms by describing light as waves, suggested that electromagnetic energy could only be emitted in quantized form, i.e. the energy could only be a multiple of an elementary unit $E = hv$, where h is Planck's constant and v is the frequency of the radiation.

Johannes Rydberg refines the expression for observed hydrogen line spectrums.

1901 Max Planck calculated the value to Planck's constant to be $6.6260693 \times 10^{-34}$J s. He also published his quantum theory.

Frederick Soddy and Ernest Rutherford discovered nuclear transmutation when they found that radioactive thorium was converting itself into radium through a process of nuclear decay.

1903 Ernest Rutherford establishes the fact that alpha particles have a positive charge. This allowed for later (1909) scientists to establish alpha particles as helium nuclei.

1905 Albert Einstein determines the equivalence of matter and energy.

Albert Einstein first explained the effects of Brownian motion as caused by the kinetic energy (i.e., movement) of atoms, which was subsequently, experimentally verified by Jean Baptiste Perrin, thereby settling the century-long dispute about the validity of John Dalton's atomic theory.

Albert Einstein published his Special Theory of Relativity.

Albert Einstein explained the photoelectric effect (1839), i.e. that shining light on certain materials can function to eject electrons from the material, he postulated, as based on Planck's quantum hypothesis (1900), that light itself consists of individual quantum particles (photons).

1908 The Paschen series of hydrogen was discovered.

Hans Geiger develops the Geiger counter, a device capable of detecting radiation. The device proved exceedingly useful for later experiments conducted using radioactive sources.

1909 Ernest Rutherford and Thomas Royds demonstrated that alpha particles are doubly ionized helium atoms.

Hans Geiger and Ernest Marsden, under the supervision of Ernest Rutherford, scatter alpha particles off a gold foil and observe large angles of scattering, suggesting that atoms have a small, dense, positively charged nucleus.

Geoffrey Ingram Taylor demonstrated that interference patterns of light were generated even when the light energy introduced consisted of only one photon. This discovery of the wave-particle duality of matter and energy was fundamental to the later development of quantum field theory.

1911 Ernest Rutherford explains the result from the Geiger-Marsden experiment and proposes his nuclear model of the atom.

Lise Meitner and Otto Hahn performed an experiment that showed that the energies of electrons emitted by beta decay had a continuous rather than discrete spectrum. This was in apparent contradiction to the law of conservation of energy, as it appeared that energy was lost in the beta decay process. A second problem was that the spin of the Nitrogen-14 atom was 1, in contradiction to the Rutherford prediction of ½. These anomalies were later explained by the discoveries of the neutrino and the neutron.

1913 Robert Andrews Millikan published the results of his "oil drop" experiment, in which he precisely determines the electric charge of the electron. Determination of the fundamental unit of electric charge made it possible to calculate the Avogadro constant (which is the number of atoms or molecules in one mole of any substance) and thereby to determine the atomic weight of the atoms of each element.

Niels Bohr proposed his planetary model of the atom, along with the concept of stationary energy states to explain the Rydberg formula (1888), which correctly modeled the light emission spectra of atomic hydrogen, and thus accounted for the spectrum of hydrogen.

1914 James Franck & Gustav Hertz confirmed the existence of stationary states through an electron scattering experiment.

Ernest Rutherford proposes that the positively charged nucleus contains protons.

James Chadwick showed that the primary beta spectrum is continuous but contains an energy anomaly.

1915 Albert Einstein first presented to the Prussian Academy of Science what are now known as the Einstein field equations. These equations specify how the geometry of space and time is influenced by whatever matter is present, and form the core of Einstein's General Theory of Relativity.

1916 Arnold Sommerfield, in order to account for the Zeeman effect (1896), i.e. that atomic absorption or emission spectral lines change when the light source is subjected to a magnetic field, suggested there might be “elliptical orbits” in atoms in addition to spherical orbits.

The Lyman series of hydrogen was discovered.

Albert Einstein develops the theory for the conservation of momentum-energy for general relativity. He stated that momentum and energy are intertwined just as space and time are. From this it follows that mass, energy and momentum will cause the space-time continuum to be curved.

1917 Albert Einstein introduces the idea of stimulated radiation emission.

1918 Ernest Rutherford noticed that, when alpha particles were shot into nitrogen gas, his scintillation detectors showed the signatures of hydrogen nuclei. Rutherford determined that the only place this hydrogen could have come from was the nitrogen, and therefore nitrogen must contain hydrogen nuclei. He thus suggested that the hydrogen nucleus, which was known to have an atomic number of 1, was an elementary particle, which he decided must be the protons hypothesized by Eugen Goldstein.

1919 Ernest Rutherford finds the first evidence for a proton.

1920 Ernest Rutherford predicts the existence of a neutron.

1921 James Chadwick and E.S. Bieler conclude that some strong force holds the nucleus together. They call this ‘strong nuclear interaction’.

1922 The Brackett series of hydrogen is discovered.

Otto Stern and Walther Gerlach did Stern-Gerlach experiment detecting discrete values of angular momentum for atoms in the ground state passing through an inhomogeneous magnetic field leading to the discovery of the spin of the electron.

1923 Arthur Compton found that X-ray wavelengths increase due to scattering of the radiant energy by "*free electrons*". The scattered quanta have less energy than the quanta of the original ray. This discovery, known as the "Compton effect" or "Compton scattering" demonstrates the "*particle*" concept of electromagnetic radiation.

Louis de Broglie generalizes wave-particle duality by suggesting that particles of matter are also wavelike. He postulated that electrons in motion are associated with waves the lengths of which are given by Planck's constant *h* divided by the momentum of the$mv = p$ of the electron: $\lambda = h / mv = h / p$.

1924 Satyendra Nath Bose and Albert Einstein find a new way to count quantum particles, later called Bose-Einstein statistics, and they predict that extremely cold atoms should condense into a single quantum state, later known as a Bose-Einstein condensate.

The Pfund series of hydrogen is discovered.

1925 Wolfgang Pauli formulates the exclusion principle for electrons in an atom.

Werner Heisenberg, Max Born, and Pascual Jordan develop matrix mechanics, the first version of quantum mechanics, and make an initial step toward quantum field theory.

Walther Bothe and Hans Geiger demonstrate that energy and mass are conserved in atomic processes.

1926 Erwin Schrödinger develops a second description of quantum physics, called wave mechanics which describes the behavior of quantum systems for bosons. It is later known as the Schrödinger equation. He later proved this to equal Heisenberg's matrix mechanics.

Enrico Fermi and Paul A.M. Dirac find that quantum mechanics requires a second way to count particles, Fermi-Dirac statistics, opening the way to solid-state physics.

Max Born gave a probability interpretation of quantum mechanics.

Gilbert Lewis coined the term photon, which he derived from the Greek word for light, φως (transliterated phôs).

1927 Werner Heisenberg formulates the uncertainty principle: the more you know about a particle's energy, the less you know about the time of the energy (and vice versa.) The same uncertainty applies to momentum and position.

Clinton Davisson, Lester Germer and George Paget Thompson confirm the wavelike nature of electrons through electron diffraction by a crystal.

Niels Bohr develops his principle of complemetarity in October 1927 Fifth Solvay International Conference.

Charles Drummond Ellis (along with James Chadwick and colleagues) finally established clearly that the beta decay spectrum is in fact continuous and not discrete, posing a problem that would later by solved by theorizing (and later discovering) the existence of the neutrino.

1928 Paul Dirac, in the Dirac equations, integrated the principal of special relativity with quantum mechanics and hypothesized the existence of the positron (anti-electron).

1930 Quantum mechanics and special relativity are well established. There are just three fundamental particles: protons, electrons, and photons. Max Born, after learning of the Dirac equation, said, "Physics as we know it will be over in six months."

Wolfgang Pauli in a famous letter suggested that, in addition to electrons and protons, atoms also contained an extremely light neutral particle which he called the "neutron." He suggested that this "neutron" was also emitted during beta decay and had simply not yet been observed. Later it was determined that this particle was actually the almost massless neutrino.

Erwin Schrödinger predicts the zitterbewegung motion effect. The motion is a theoretical circular motion formula for elementary particles, in particular electrons. This motion is responsible for producing their spin and magnetic moment.

1931 Paul Dirac realized that the positively-charged particles required by his equation are new objects (he calls them "positrons"). They are exactly like electrons, but positively charged. This is the first example of antiparticles.

Enrico Fermi renamed Pauli's "neutron" to neutrino in order to distinguish it from the then-hypothetical possibility of a much more massive neutron.

Walther Bothe and Herbert Becker found that if the very energetic alpha particles emitted from polonium fell on certain light elements, specifically beryllium, boron, or lithium, an unusually penetrating radiation was produced. At first this radiation was thought to be gamma radiation, although it was more penetrating than any gamma rays known, and the details of experimental results were very difficult to interpret on this basis. Some scientists began to hypothesize the possible existence of another fundamental, atomic particle.

1932 Irène Joliot-Curie and Frédéric Joliot showed that if the unknown radiation generated by alpha particles fell on paraffin or any other hydrogen-containing compound, it ejected protons of very high energy. This was not in itself inconsistent with the proposed gamma ray nature of the new radiation, but detailed quantitative analysis of the data became increasingly difficult to reconcile with such a hypothesis.

James Chadwick performed a series of experiments showing that the gamma ray hypothesis for the unknown radiation produced by alpha particles was untenable, and that the new particles must be the neutrons hypothesized by Enrico Fermi. Chadwick suggested that, in fact, the new radiation consisted of uncharged particles of approximately the same mass as the proton, and he performed a series of experiments verifying his suggestion.

Carl David Anderson experimentally proved the existence antimatter, an antielectron called the positron.

Mark Oliphant, building upon the nuclear transmutation experiments of Ernest Rutherford done a few years earlier, first observed fusion of light nuclei (hydrogen isotopes) in 1932. The steps of the main cycle of nuclear fusion in stars were subsequently worked out by Hans Bethe throughout the remainder of that decade.

1933 Leó Szilárd first theorized the concept of a nuclear chain reaction. He filed a patent for his idea of a simple nuclear reactor the following year.

Einstein propounded there must be some 'hidden variable' somewhere that is responsible for the uncertainty in QM.

1934 Enrico Fermi puts forth a theory of beta decay that introduces the weak interaction. This is the first theory to explicitly use neutrinos and particle flavor changes.

Enrico Fermi studied the effects of bombarding uranium isotopes with neutrons.

Hideki Yukawa combines relativity and quantum theory to describe nuclear interactions by an exchange of new particles (mesons called "pions") between protons and neutrons. From the size of the nucleus, Yukawa concludes that the mass of the conjectured particles (mesons) is about 200 electron masses. This is the beginning of the meson theory of nuclear forces.

1935 Einstein-Podolsky-Rosen paradox was proposed.

1936 Carl D. Anderson discovered muon in cosmic rays, a particle of 200 electron masses. While at first physicists thought it was Yukawa's pion, it was later (1947) discovered to be a muon.

1938 Otto Hahn and Fritz Strassmann sent a manuscript to Naturwissenschaften reporting they had detected the element barium after bombarding uranium with neutrons. Simultaneously, they communicated these results to Lise Meitner. Meitner, and her nephew Otto Robert Frisch, correctly interpreted these results as being nuclear fission. Frisch confirmed this experimentally on 13 January 1939.

E.C.G. Stückelberg observes that protons and neutrons do not decay into any combination of electrons, neutrinos, muons, or their antiparticles. The stability of the proton cannot be explained in terms of energy or charge conservation; he proposes that heavy particles are independently conserved.

1939 Leó Szilárd and Enrico Fermi discovered neutron multiplication in uranium, proving that a chain reaction was indeed possible.

1941 C. Moller and Abraham Pais introduce the term "nucleon" as a generic term for protons and neutrons.

1942 Kan-Chang Wang first proposed the use of beta capture to experimentally detect neutrinos.

Enrico Fermi created the first artificial self-sustaining nuclear chain reaction, called Chicago Pile-1 (CP-1), in a racquets court below the bleachers of Stagg Field at the University of Chicago on December 2, 1942.

1945 Manhattan Project: First nuclear fission explosion.

1947 Physicists realize that the cosmic ray particle thought to be Yukawa's meson is instead a "muon," the first particle of the second generation of matter particles to be found. This discovery was completely unexpected -- I.I. Rabi comments "who ordered that?" The term "lepton" is introduced to describe objects that do not interact too strongly (electrons and muons are both leptons).

A meson that does interact strongly is found in cosmic rays, and is determined to be the pion.

Physicists develop procedures to calculate electromagnetic properties of electrons, positrons, and photons. Introduction of Feynman diagrams.

G. D. Rochester and C. C. Butler published two cloud chamber photographs of cosmic ray-induced events, one showing what appeared to be a neutral particle decaying into two charged pions, and one which appeared to be a charged particle decaying into a charged pion and something neutral. The estimated mass of the new particles was very rough, about half a proton's mass. More examples of these "V-particles" were slow in coming, and they were soon given the name kaons.

1948 The Berkeley synchro-cyclotron produces the first artificial pions.

Sin-Itiro Tomonaga and Julian Schwinger independently introduced perturbative renormalization as a method of correcting the original Lagrangian of a quantum field theory so as to eliminate an infinite series of counterterms that would otherwise result.

Richard Feynman stated the path integral formulation of quantum mechanics.

Richard Feynman, Julian Schwinger, and Sin-Itiro Tomonaga develop the first complete theory of the interaction of photons and electrons, quantum electrodynamics, which accounts for the discrepancies in the Dirac theory.

1949 Freeman Dyson determined the equivalence of the formulations of quantum electrodynamics that existed by that time - Richard Feynman's diagrammatic path integral formulation and the operator method developed by Julian Schwinger and Sin-Itiro Tomonaga. A by-product of that demonstration was the invention of the Dyson series.

Enrico Fermi and C.N. Yang suggest that a pion is a composite structure of a nucleon and an anti-nucleon. This idea of composite particles is quite radical.

Discovery of K+ via its decay.

1950 The neutral pion is discovered.

1951 Two new types of particles are discovered in cosmic rays. They are discovered by looking a V-like tracks and reconstructing the electrically-neutral object that must have decayed to produce the two charged objects that left the tracks. The particles were named the lambda0 and the K0.

1952 Discovery of particle called delta: there were four similar particles (delta++, delta+, delta0, and delta-.)

Donald Glaser invents the bubble chamber. The Brookhaven Cosmotron, a 1.3 GeV accelerator, starts operation.

David Bohm’s interpretation of QM.

1953 The beginning of a "particle explosion" -- a true proliferation of particles.

1953 - 57 Scattering of electrons off nuclei reveals a charge density distribution inside protons, and even neutrons. Description of this electromagnetic structure of protons and neutrons suggests some kind of internal structure to these objects, though they are still regarded as fundamental particles.

1954 C.N. Yang and Robert Mills developed a new class of theories called "gauge theories" for nonabelian groups, leading to the successful formulation of both electroweak unification and quantum chromodynamics thus forming the basis of the Standard Model, although not realized at the time.

1955 & 1956 Murray Gell-Mann and Kazuhiko Nishijima independently derived the Gell-Mann–Nishijima formula, which relates the baryon number B, the strangeness S, and the isospin I_z of hadrons to the charge Q, eventually leading to the systematic categorization of hadrons and, ultimately, the Quark Model of hadron composition.

1956 P. Kuroda predicted that self-sustaining nuclear chain reactions should occur in natural uranium deposits.

Clyde L. Cowan and Frederick Reines experimentally proved the existence of the neutrino.

1957 John Bardeen, Leon Cooper, and J. Robert Schrieffer show that electrons can form pairs whose quantum properties allow them to travel without resistance, providing an explanation for the zero electrical resistance of superconductors. This theory was later termed the BCS theory.

William Alfred Fowler, Margaret Burbidge, Geoffrey Burbidge, and Fred Hoyle explained how the abundances of essentially all but the lightest chemical elements could be explained by the process of nucleosynthesis in stars.

Hugh Everett's interpretation of QM.

1957-59 Julian Schwinger, Sidney Bludman, and Sheldon Glashow, in separate papers, suggest that all weak interactions are mediated by charged heavy bosons, later called W+ and W-. Actually, it was Yukawa who first discussed boson exchange twenty years earlier, but he proposed the pion as the mediator of the weak force.

1959 Yakir Aharonov and David Bohm predict that a magnetic field affects the quantum properties of an electron in a way that is forbidden by classical physics. The Aharonov-Bohm effect is observed in 1960 and hints at a wealth of unexpected macroscopic effects.

1960 Theodore Maiman builds the first practical laser, building on work by Charles Townes, Arthur Schawlow, and others.

1961 Clauss Jönsson performed Young's double-slit experiment (1909) for the first time with a particle other than photons by using electrons and with similar results, confirming that massive particles also behaved according to the wave-particle duality that is a fundamental principal of quantum field theory.

Sheldon Lee Glashow extended the electroweak unification models developed by Julian Schwinger by including a short range neutral current, the Z0. The resulting symmetry structure that Glashow proposed, SU(2) X U(1), formed the basis of the accepted theory of the electroweak interactions.

As the number of known particles keep increasing, a mathematical classification scheme to organize the particles (the group SU(3)) helps physicists recognize patterns of particle types.

1962 Leon M. Lederman, Melvin Schwartz and Jack Steinberger showed that more than one type of neutrino exists by detecting interactions of the muon neutrino (already hypothesised with the name "neutretto") (previously there was electron neutrino). This was earlier inferred from theoretical considerations.

Murray Gell-Mann and Yuval Ne'eman independently classified the hadrons according to a system that Gell-Mann called the "Eightfold Way," and which ultimately led to the quark model(1964) of hadron composition.

Jeffrey Goldstone, Yoichiro Nambu, Abdus Salam, and Steven Weinberg developed what is now known as Goldstone's Theorem, in which it was proved that, if there is continuous symmetry transformation under which the Lagrangian is invariant, then either the vacuum state is also invariant under the transformation, or there must exist spinless particles of zero mass, thereafter called Nambu-Goldstone bosons.

1963 Nicola Cabibbo developed the mathematical matrix by which the first two (and ultimately three) generations of quarks could be predicted.

1964 Murray Gell-Mann and George Zweig independently proposed the quark model of hadrons, predicting the arbitrarily named up, down, and strange quarks. Gell-Mann is credited with coining the term "quark," which he found in James Joyce's book *Finnegans Wake*.

François Englert,Robert Brout, Peter Higgs, Gerald Guralnik, C. R. Hagen, and Tom Kibble postulated that a fundamental quantum field, now called the Higgs field, permeates space and, by way of the Higgs mechanism, provides mass to all the elementary subatomic particles that interact with it. While the Higgs field is postulated to confer mass on quarks and leptons, it represents only a tiny portion of the masses of other subatomic particles, such as protons and neutrons. In these, gluons that bind quarks together confer most of the particle mass. The Higgs mechanism, which gives mass to vector bosons, was theorized in 1964 by François Englert and Robert Brout. In October of the same year, Peter Higgs, working from the ideas of Philip Anderson reached the same conclusions; and, independently, by Gerald Guralnik, C. R. Hagen, and Tom Kibble, who worked out the results by the spring of 1963.

Sheldon Lee Glashow and James Bjorken predicted the existence of the charm quark. The addition was proposed because it allowed for a better description of the weak interaction (the mechanism that allows quarks and other particles to decay), equalized the number of known quarks with the number of known leptons, and implied a mass formula that correctly reproduced the masses of the known mesons.

John S. Bell proposes an experimental test, "Bell's inequalities," of whether quantum mechanics provides the most complete possible description of a system.

1965 O.W. Greenberg, M.Y. Han, and Yoichiro Nambu introduce the quark property of **color** charge. All observed hadrons are color neutral.

1967 Steven Weinberg and Abdus Salam separately propose a theory that unifies electromagnetic and weak interactions into the electroweak interaction, where they described Yang-Mills Theory using the SU(2) X U(1) supersymmetry group, thereby yielding a mass for the W particle of the Weak Interaction via spontaneous symmetry breaking. . Their theory requires the existence of a neutral, weakly interacting boson (now called the Z^0) that mediates a weak interaction that had not been observed at that time. They also predict an additional massive boson called the Higgs Boson that has not yet been observed.

1968 Stanford University: Deep inelastic scattering experiments at the Stanford Linear Accelerator Center (SLAC) showed that the proton contained much smaller, point-like objects and was therefore not an elementary particle. Physicists at the time were reluctant to identify these objects with quarks, instead calling them "partons" — a term coined by Richard Feynman. The objects that were observed at SLAC would later be identified as up and down quarks. Nevertheless, "parton" remains in use as a collective term for the constituents of hadrons (quarks, antiquarks, and gluons). The strange quark's existence was indirectly validated by the SLAC's scattering experiments: not only was it a necessary component of Gell-Mann and Zweig's three-quark model, but it provided an explanation for the kaon (K) and pion (π) hadrons discovered in cosmic rays in 1947

1970 Sheldon Lee Glashow, John Iliopoulos and Luciano Maiani presented further reasoning for the existence of the as-yet undiscovered charm quark.

1971 Martinus J. G. Veltman and Gerardus 't Hooft showed that, if the symmetries of Yang-Mills Theory were to be broken according to the method suggested by Peter Higgs, then Yang-Mills theory can be renormalized. The renormalization of Yang-Mills Theory predicted the existence of a massless particle, called the gluon, which could explain the nuclear Strong Force. It also explained how the particles of the Weak Interaction, the W and Z bosons, obtained their mass via spontaneous symmetry breaking and the Yukawa interaction.

1972 Francis Perrin discovered the existence of "natural nuclear fission reactors" in uranium deposits in Oklo, Gabon, where analysis of isotope ratios demonstrated that self-sustaining, nuclear chain reactions had occurred. The conditions under which a natural nuclear reactor could exist were predicted in 1956 by P. Kuroda.

1973 Makoto Kobayashi and Toshihide Maskawa noted that the experimental observation of CP violation could be explained if an additional pair of quarks existed. The two new quarks were eventually named top and bottom.

Donald Perkins, spurred by a prediction of the Standard Model, re-analyzes some old data from CERN and finds indications of weak interactions with no charge exchange (those due to a Z^0 exchange.)

A quantum field theory of strong interaction is formulated. This theory of quarks and gluons (now part of the Standard Model) is similar in structure to quantum electrodynamics (QED), but since strong interaction deals with color charge this theory is called quantum chromodynamics (QCD). Quarks are determined to be real particles, carrying a color charge. Gluons are massless quanta of the strong-interaction field. This strong interaction theory was first suggested by Harald Fritzsch and Murray Gell-Mann.

David Politzer, David Gross, and Frank Wilczek discover that the color theory of the strong interaction has a special property, now called "asymptotic freedom." The property is necessary to describe the 1968-69 data on the substrate of the proton.

1974 Burton Richter and Samuel Ting : Charm quarks were produced almost simultaneously by two teams in November 1974 (see November Revolution) — one at SLAC under Burton Richter, and one at Brookhaven National Laboratory under Samuel Ting. The charm quarks were observed bound with charm antiquarks in mesons. The two discovering parties had independently assigned the discovered meson two different symbols, J and ψ; thus, it became formally known as the J/ψ meson. The discovery finally convinced the physics community of the quark model's validity

1975 Martin Lewis Perl with his colleagues at the SLAC–LBL group, he detected the tauon in a series of experiments between 1974 and 1977.

1977 Leon Lederman observed the bottom quark with his team at Fermilab. This discovery was a strong indicator of the top quark's existence: without the top quark, the bottom quark would have been without a partner that was required by the mathematics of the theory.

1978 Charles Prescott and Richard Taylor observed a Z^0 mediated weak interaction in the scattering of polarized electrons from deuterium which shows a violation of parity conservation, as predicted by the Standard Model, confirming the theory's prediction.

1979 Strong evidence for a gluon radiated by the initial quark or antiquark if found at PETRA, a colliding beam facility at the DESY laboratory in Hamburg.

1982 Alain Aspect carries out an experimental test of Bell's inequalities and confirms the completeness of quantum mechanics.

1983 Carlo Rubbia and Simon van der Meer : Unambiguous signals of W particles were seen in January 1983 during a series of experiments conducted by Carlo Rubbia and Simon van der Meer at the Super Proton Synchrotron. The actual experiments were called UA1 (led by Rubbia) and UA2 (led by Peter Jenni), and were the collaborative effort of many people. Simon van der Meer was the driving force on the use of the accelerator. UA1 and UA2 found the Z particle a few months later, in May 1983.

1989 Experiments carried out in SLAC and CERN strongly suggest that there are three and only three generations of fundamental particles. This is inferred by showing that the Z^0-boson lifetime is consistent only with the existence of exactly three very light (or massless) neutrinos.

1995 Fermilab: After eighteen years of searching at many accelerators, the CDF and D0 experiments at Fermilab discover the top quark at the unexpected mass of 175 GeV, much greater than had been previously expected — almost as great as a gold atom. No one understands why the mass is so different from the other five quarks.

Eric Cornell, Carl Wieman and Wolfgang Ketterle : The first "pure" Bose–Einstein condensate was created by Eric Cornell, Carl Wieman, and co-workers at JILA. They did this by cooling a dilute vapor consisting of approximately two thousand rubidium-87 atoms to below 170 nK using a combination of laser cooling and magnetic evaporative cooling. About four months later, an independent effort led by Wolfgang Ketterle at MIT created a condensate made of sodium-23. Ketterle's condensate had about a hundred times more atoms, allowing him to obtain several important results such as the observation of quantum mechanical interference between two different condensates. Eric Cornell, Carl Wieman, and Wolfgang Ketterle trap clouds of metallic atoms cooled to less than a millionth of a degree above absolute zero, producing Bose-Einstein condensates, which were first predicted 70 years earlier. This accomplishment leads to the creation of the atom laser and superfluid gases.

2000 CERN scientists publish experimental results in which they claim to have observed indirect evidence of the existence of a quark-gluon plasma, which they call a "new state of matter."