A Century of Particle Physics (1)

(An asterisk (*) denotes Nobel-prize winning work)

1896 Bequerel* discovers radioactivity
(It ruined his photographic plates)

1899 Thomson* identifies cathode rays as electrons
(Pioneering work by Hertz/Lenard in Bonn)

1900 Planck* introduces the quantum to explain the black body spectrum ($\hbar$)

1905 Einstein formulates special relativity (c)

1905 Einstein* uses light quantum to explain the photoelectric effect ($\gamma, E = \hbar\nu$)

1911 Rutherford finds evidence for the atomic nucleus

1913 Bohr* invents a quantum theory of atomic spectra ($a_0 = \hbar^2/e^2 m_e$)

1920 Rutherford names the proton (p)

1925 Pauli* invents the exclusion principle

1925 Born*, Heisenberg*, Jordan describe the foundations of quantum mechanics

1926 Schrödinger* develops wave equation

1926 Born* introduces the probabilistic interpretation of the wave function

1928 Dirac* invents the relativistic wave equation and predicts the magnetic moment of the electron ($g = 2$)

A Century of Particle Physics (2)

1929 Pauli proposes the neutrino as a way to conserve energy in β decay

1930 Oppenheimer calculates the self-energy of the electron.
Unfortunately, it diverges.

1931 Dirac predicts the positron

1931 Anderson* finds evidence for the positron (e^+)

1932 Chadwick* finds evidence for the neutron (n)

1932 Heisenberg surmises nuclei are made up of protons and neutrons

1933 Fermi proposes a field theory for β decay
$(n \to p + e^- + \bar{\nu}_e)$

1934 Yukawa* proposes a field theory to bind nuclei.
Since the force is short-range, he postulates
a massive exchange particle (a "meson").

1936 Muons found by Anderson in cosmic rays (μ)

1947 Kusch* and Foley measure the anomalous magnetic moment of the electron $(g_e - 2 > 0)$

1947 Lattes, Occhialini and Powell* find the pion in cosmic rays and observe its decay to a muon (+?)

1947 Rochester and Powell find "V" events in cosmic rays

1948 Feynman, Schwinger and Tomonaga* formulate quantum electrodynamics

A Century of Particle Physics (3)

1950 – 1960 Many mesons and baryons discovered
$K^{\pm}, \Lambda, K^0, \Delta^{++}, \Xi^-, \Sigma^{\pm}, \bar{p}, \bar{n}, \Sigma^0, \Xi^0$

1956 T.D.Lee and C.N.Yang* propose ways to test spatial mirror symmetry (parity)

1956 Reines, Cowan* detect reactor neutrino's (ν_e)

1957 C.S.Wu and collaborators find that parity is maximally violated in β decay

1957 Schwinger, Lee and Yang develop the idea of the intermediate vector boson to fix Fermi's theory

1958 Feynman and Gell-Mann formulate the V-A theory of weak interactions

1961 Glashow introduces an *electrically neutral* intermediate vector boson for weak interactions

1962 Lederman, Schwarz and Steinberger* find that neutrino's produced from muons make *only* muons
$\nu_\mu + p \rightarrow \mu^+ + n$

1963 Cabibbo introduces quark mixing angles for weak hadronic currents

1964 Gell-Mann* and Zweig introduce SU(3) group (quarks) to explain the mesons and baryons, predict triply strange baryon.
It is discovered at Brookhaven $(\Omega^{\pm})$

1964 Higgs and others formulate field theory with spontaneous symmetry breaking and massive vector bosons

A Century of Particle Physics (4)

1964 Fitch and Cronin* show that CP symmetry is violated in K decays

1964 Salam* and Ward formulate unification of electromagnetic and weak forces

1967 Weinberg* adds neutral currents to electroweak unification

1969 Friedman, Kendall, and Taylor* measure scaling property of deep inelastic $e^- p$ scattering

1969 Bjorken and Feynman develop partonic picture of proton using deep inelastic $e^- p$ scattering results

1970 Glashow, Iliopoulos and Maiani propose lepton/quark symmetry and existence of charm quark

1971 't Hooft and Veltman* use Higgsian spontaneous symmetry breaking to renormalize the electroweak theory

1973 Kobayashi and Maskawa show how to incorporate CP symmetry violation in the quark mixing matrix

1973 Weak neutral currents found at CERN in a bubble chamber neutrino experiment

1973 Gross and Wilczek, Politzer develop the idea of asymptotic freedom to explain quark confinement

A Century of Particle Physics (5)

1974 Discovery of the charm/anti-charm quark bound state* at Brookhaven and SLAC (c)
(The "November revolution")

1975 Discovery of charmed mesons at SLAC

1975 Discovery of the tau lepton* at SLAC($\tau^{\pm}$)

1977 Discovery of the bottom/anti-bottom quark bound state at Fermilab (b)

1979 Experimental evidence for the gluon found at DESY in e^+e^- interactions (g)

1983 Discovery of the intermediate vector bosons* at CERN ($W^{\pm}, Z$)

1989 Evidence from e^+e^- interactions at SLAC and CERN that there are only 3 light neutrino's

1995 Discovery of the top quark in $p\bar{p}$ interactions at Fermilab (t)

1996 Strong evidence for lepton number violation from solar neutrino detectors (oscillations, m_ν)

1997 Evidence for lepton number violation from large underground water Cerenkov detector in Japan detecting atmospheric neutrino's (oscillations in the earth)