QCD - From flavor SU(3) to effective field theory

The INT @ 20
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Harvard

I started with a timeline that exists on the web - http://www.weburbia.com/pg/historia.htm - "From the Greek philosophers to string theorists, this is the chronology of discoveries in physics and cosmology."

1918 - Herman Weyl - guage theory
1919 - Ernest Rutherford - existence of the proton in nucleus
1920 - Ernest Rutherford - prediction of neutron
1921 - Bieler and Chadwick - evidence for a strong nuclear interaction
1923 - Louis de Broglie - predicts wave nature of particles
1924 - Bose and Einstein - statistics of photons and Bose-Einstein condensate
1924 - Wolfgang Pauli - the exclusion principle
1925 - Werner Heisenberg - transition amplitude theory of quantum mechanics
1925 - Born and Jordan - matrix interpretation of Heisenberg's quantum mechanics
1925 - Paul Dirac - q-number theory of general quantum mechanics
1925 - Pascual Jordan - second quantisation
1925 - Goudsmit and Uhlenbeck - electron spin
1925 - Enrico Fermi - statistics of electrons
1926 - Eckart, Pauli, Schroedinger - equivalence of wave equation and matrix mechanics
1926 - Max Born - probability interpretation of wave function
1926 - Albert Einstein - "God does not play dice"
1926 - Paul Dirac - distinction between bosons and fermions, symmetry and anti-symmetry of wave function
1926 - Born, Heisenberg, Jordan - model of a quantised field
1926 - Wolfgang Pauli - momentum and position cannot be known simultaneously
1926 - Werner Heisenberg - the uncertainty principle
1927 - Paul Dirac - quantisation of electromagnetic field, bosonic creation and anihilation operators, virtual particles, zero point energy
1927 - Eugene Wigner - conservation of parity
1927 - Niels Bohr - Copenhagen interpretation of Quantum Mechanics
1928 - Condon, Gamow, Gurney - alpha emission is due to quantum tunnelling
1928 - Paul Dirac - relativistic equation of the spin-half electron
1928 - Jordan, Pauli - quantum field theory of free fields
1928 - Rolf Wideroe - first prototype high energy accelerator
1928 - Heisenberg, Weyl - group representation theory in quantum mechanics
1929 - Ernest Lawrence - cyclotron
1929 - Robert van de Graaff - Van de Graaff generator
1929 - Heisenberg, Pauli - interacting quantum field theory and divergences
1929 - J. Robert Oppenheimer - divergence of electron self-energy
1929 - Paul Dirac - electron sea and hole theory
1930 - Becker, Bothe - observed neutral rays later identified as neutrons
1930 - Paul Dirac - systematic canonical quantisation
1930 - Hartree and Fock - multi-particle quantum mechanics
1931 - Dirac, Oppenheimer, Weyl - prediction of anti-matter
1931 - Wolfgang Pauli - neutrino as explanation for missing energy and spin in weak nuclear decay
1931 - Eugene Wigner - symmetry in quantum mechanics
1931 - Paul Dirac - magnetic monopoles can explain quantum of charge
1932 - Raman and Bhagavantam - Verification that photon is spin one
1932 - James Chadwick - identified the neutron
1932 - Carl Anderson - positron from cosmic rays
1932 - Cockroft and Walton - linear proton accelerators to 700 keV and verification of mass/energy equivalence
1932 - Dmitri Iwanenko - Neutron as a constituent of nucleus
1932 - Vladimir Fock - Fock space
1932 - Urey, Brickwedde, Murphy, Washburn - deuterium
1932 - Werner Heisenberg - Nucleus is composed of protons and neutrons
1932 - Lev Davidovich Landau - proposed existence of neutron stars
1933 - Blackett and Occhialini - electron-positron creation and annihilation
1933 - Esterman, Frisch and Stern - measurement of proton magnetic moment
1934 - Chadwick and Goldhaber - precise measurement of neutron mass
1934 - Chadwick and Goldhaber - measurement of nuclear force
1934 - Francis Perrin - neutrino is massless
1934 - Joliot and Curie-Joliot - induced radioactivity
1934 - Enrico Fermi - Fermi theory of weak interaction and beta decay
1934 - Esterman and Stern - magnetic moment of neutron
1934 - Paul Dirac - polarisation of the vacuum and more divergence in QED
1935 - Yukawa, Stueckelberg - theory of strong nuclear force and the pi-meson
1935 - J. Robert Oppenheimer - spin statistics
1936 - Anderson and Neddermeyer - muon in cosmic rays
1936 - Breit and Coll - isotopic spin
1936 - Alan Turing - computability
1937 - Majorana - symmetric theory of electron and positron
1937 - Julian Schwinger - Neutron spin is half
1937 - Blau, Wambacher - photographic emulsion as particle detector
1937 - Bloch and Nordsieck - operator normal ordering
1937 - John Wheeler - S-matrix theory
1938 - Hendrick Kramers - mass renormalisation
1939 - Bloch and Alvarez - measurement of the neutron magnetic moment
1939 - Rossi, Van Norman, Hilbery - Muon decay
1941 - Rossi and Hall - Muon decay used to verify relativistic time dilation
1943 - Ernest Stueckelberg - renormalisation of QED
1943 - Sakata, Inoue - theory of pion decay to muons
1944 - Leprince-Ringuet and Lheritier - the K+ found in cosmic rays
1945 - first electronic computer ENIAC
1947 - Conversi, Pancini, Piccioni - indication that the muon is not the mediator of the strong force
1947 - Hartmut Kallman - scintillation counter
1947 - Powell, Occhialini - negative pion found
1947 - Willis Lamb - fine structure of hydrogen spectrum, the Lamb shift
1947 - Hans Bethe - renormalisation of Lamb shift calculation
1947 - Kusch and Folley - measurement of the anomolous magnetic moment of the electron
1948 - Tomonaga, Schwinger, Feynman - renormalisation of QED
1948 - Goldhaber and Goldhaber - experimental proof that beta particles are electrons
1948 - Richard Feynman - path integral approach to quantum theory
1948 - Snell and Miller - Decay of the neutron
1948 - Freeman Dyson - Equivalence of Feynman and Schwinger-Tomonaga QED
1949 - Leighton, Anderson, Seriff - Muon is spin half
1949 - Steinberger - Pi-zero decay calculation
1950 - Bjorklund, Crandall, Moyer, York - Neutral pion
1951 - Petermann, Stueckelberg - renormalisation group
1952 - Courant, Livingston, Snyder - Strong focusing principle for particle accelerators
1952 - Alvarez, Glaser - bubble chamber
1952 - Pais - associated production
1953 - Gell-Mann and Nishijima - strangeness
1954 - Yang and Mills - non-abelian gauge theory
1954 - Low and Gell-Mann - renormalisation group revisited
1955 - Gell-Mann and Pais - K long and K short
1955 - Chamberlain, Segre and Wiegand - anti-proton
1956 - Reines and Cowan - neutrino detection
1956 - Cork, Lambertson, Piccioni, Wenzel - evidence for anti-neutron
1956 - Block, Lee and Yang - weak interaction could violate parity
1956 - Reines and Cowan - anti-neutrino detection
1956 - Cook, Lambertson, Piconi, Wentzel - anti-neutron
1968 - Abdus Salam - 2-component neutrino
1957 - Friedman, Lederman, Telegdi, Wu - parity violation in weak decays
1957 - Feynman, Gell-Mann, Marshak, Sudarshan - V-A theory of weak interactions
1958 – Goldberger, Treiman – their relation
1958 - Gary Feinberg - predicts that muon neutrino is distinct from electron neutrino
1959 - Tulio Regge - theory of Regge poles
1960 - Gell-Mann and Levy - sigma model of pion and nucleon
1961 - Nambu and Jona-Lasinio - Dynamical symmetry breaking and the pion
1961 - Sheldon Glashow - introduces neutral intermediate boson of electro-weak interactions
1961 - Jeoffrey Goldstone - Theory of massless particles in spontaneous symmetry breaking (Goldstone boson)
1961 - Gell-Mann and Ne'eman - The eightfold way, SU(3) octet symmetry of hadrons
1961 - Robert Hofstadter - nucleons have an internal structure
1961 - Geoffrey Chew - nuclear democracy and the bootstrap model
1962 - Gell-Mann and Ne'eman - Prediction of Omega minus particle
1962 - Lederman, Steinberger, Schwartz - evidence for more than one type of neutrino
1963 - Samios et al - Baryon Omega minus found
1963 - Philip Anderson - Gauge theories can evade Goldstone theorem
1963 - Nicola Cabibbo - weak mixing angle
1964 - Brout, Englert, Higgs - Higgs mechanism of symmetry breaking
1964 - Weinberg - baryon number is probably not conserved
1964 - Christenson, Cronin, Fitch, Turlay - CP violation in weak interactions
1964 - Gell-Mann, Zweig - quark theory of hadrons
1964 - Gell-Mann - current algebra
1964 – Gursey, Pais, Radicati – SU(6)
1964 - Bjorken and Glashow - prediciton of charm
1964 - Salam, Ward - SU(2)xU(1) model of electro-weak unification
1965 - Thomas Kibble - Higgs mechanism for Yang-Mills theory
1965 - Greenberg, Han, Nambu - SU(3) colour symmetry to explain statistics of quark model
1966 - Sutherland - chiral U(1) problem
1966 – Weinberg – pion scattering lengths
1967 - Weinberg – nonlinear realization of chiral symmetry
1967 - Weinberg - electro-weak unification
1968 - Gabriele Veneziano - Dual resonance model for strong interaction, beginning of string theory
1968 - James Bjorken - theory of scaling behavior in deep inelastic scattering
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1989 - Isgur, Wise - heavy quark symmetry

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As in the two-triplet model mentioned in the Introduction, the mass formula of the type (27) may be derived dynamically. Instead of the charm number field, we introduce now eight gauge vector fields which behave as (1,8), namely as an octet in $SU(3)''$, but as singlets in $SU(3)'$. Since their coupling to the individual triplets is proportional to λ_i'' [the generators of $SU(3)''$], the interaction energy arising from the exchange of these vector fields will yield the first and second terms of Eq. (27). If these mesons obey again a similar type of mass formula, they will be expected to be massive compared to the ordinary mesons. However, it is not clear whether the resulting short-range character of the interaction can be readily reconciled with the postulated largeness of the interaction energy.

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