A Brief History of Particle Physics

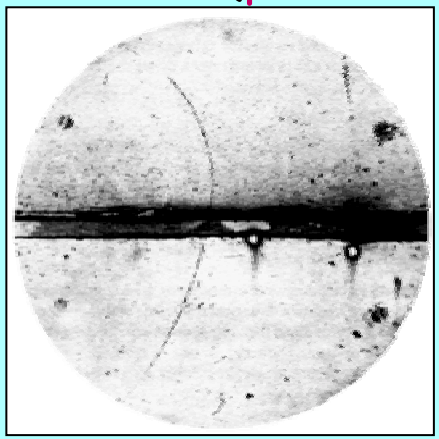
1930s

The known 'Elementary Particles' were :

- electron
- proton
- neutron (inside the nucleus)
- 'neutrino' (now anti-neutrino) in beta decay
- photon – the quantum of the electromagnetic field

1932

The positive electron (positron) discovered by Carl Anderson



C.D. Anderson, *Physical Review* **43**, 491 (1933).

Carl Anderson

The Neutron

1932
Neutron discovered by James Chadwick

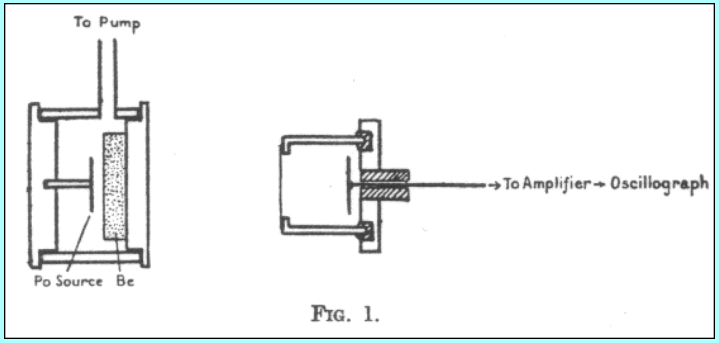
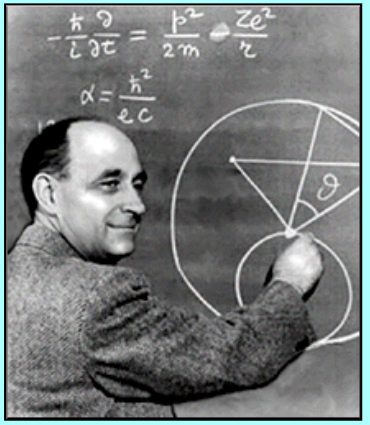


FIG. 1.


James Chadwick

1933
Fermi theory of beta decay
(weak interactions)
$n \rightarrow p + e^- + \bar{\nu}_e$


Enrico Fermi

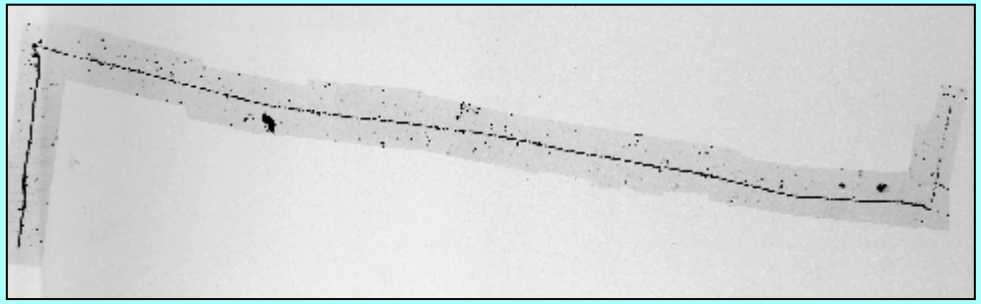
Pions and Muons

1935
Yukawa's meson hypothesis – nuclear force due to exchange of particles with mass (mesons).

Hideki Yukawa

1937
μ lepton (muon) discovered by Carl Anderson and Seth Nedermeyer. Initially assumed to be Yukawa's meson but it was too penetrating.

1946
Charged π meson (pion) discovered by Cecil Powell. The previous μ produced from π decays via $\pi^+ \rightarrow \mu^+ + \nu_\mu$.

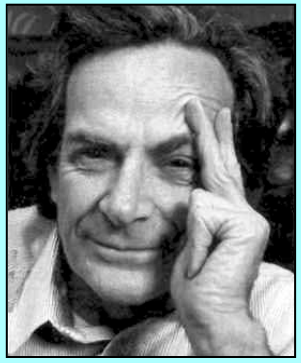


Cecil Powell

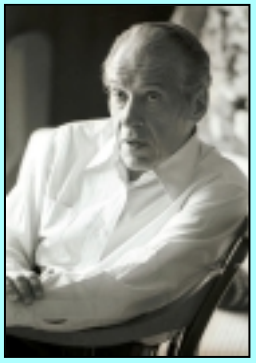
1950
Neutral pion (π^0) discovered via $\pi^0 \rightarrow \gamma + \gamma$.

A Theory of Electromagnetism

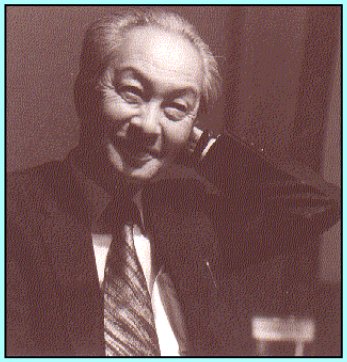
By 1950
Quantum Theory of Electromagnetism – Quantum Electrodynamics (QED) – charged particles interact via exchange of photons (γ). Richard Feynman, Julian Schwinger and Sin-itiro Tomonaga.



Richard Feynman



Julian Schwinger

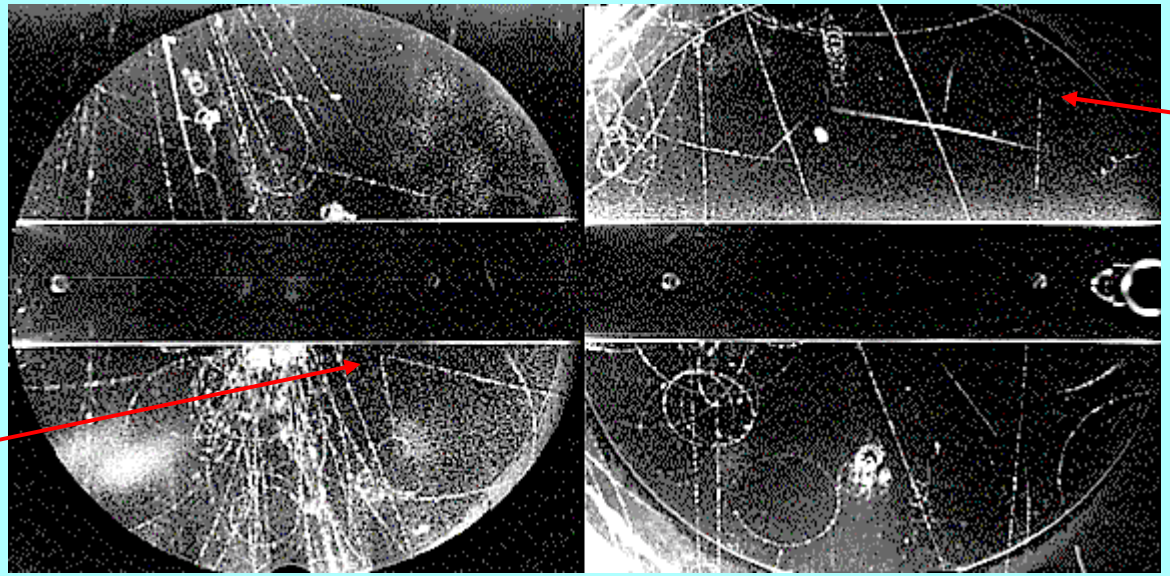


Sin-itiro Tomonaga

Strange Particles

1947

Discovery of the kaon (K meson). 'Strange' long lived particles discovered in cosmic ray events by Clifford Butler and George Rochester. Gave rise to a new quantum number 'strangeness'. Further 'V' events discovered at Brookhaven, New York in 1952/53.



Robin Marshall, University of Manchester.

Anti-matter

1955
Discovery of the anti-proton by Owen Chamberlain and Emilio Segrè.

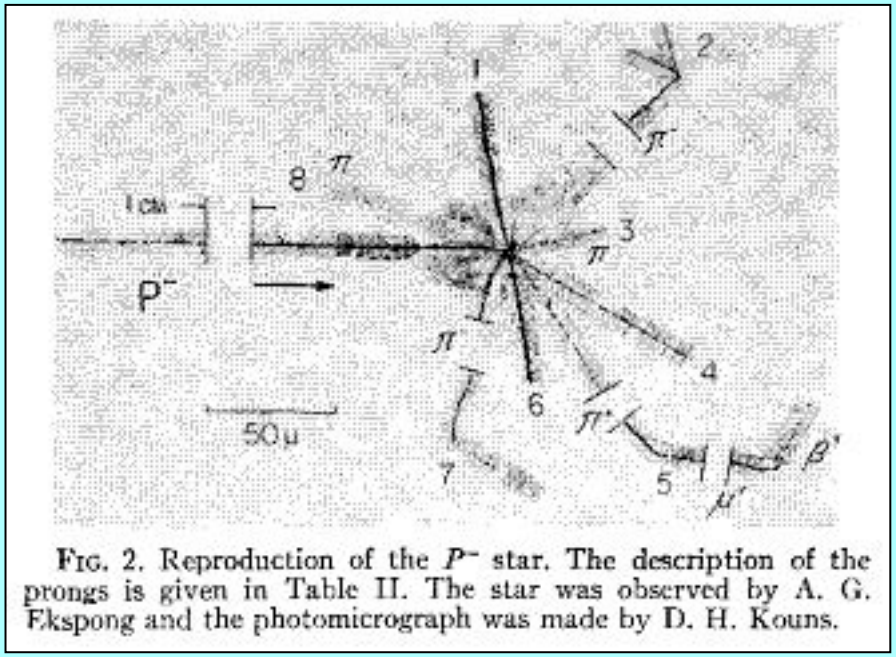


FIG. 2. Reproduction of the P^- star. The description of the prongs is given in Table II. The star was observed by A. G. Ekspong and the photomicrograph was made by D. H. Kouns.

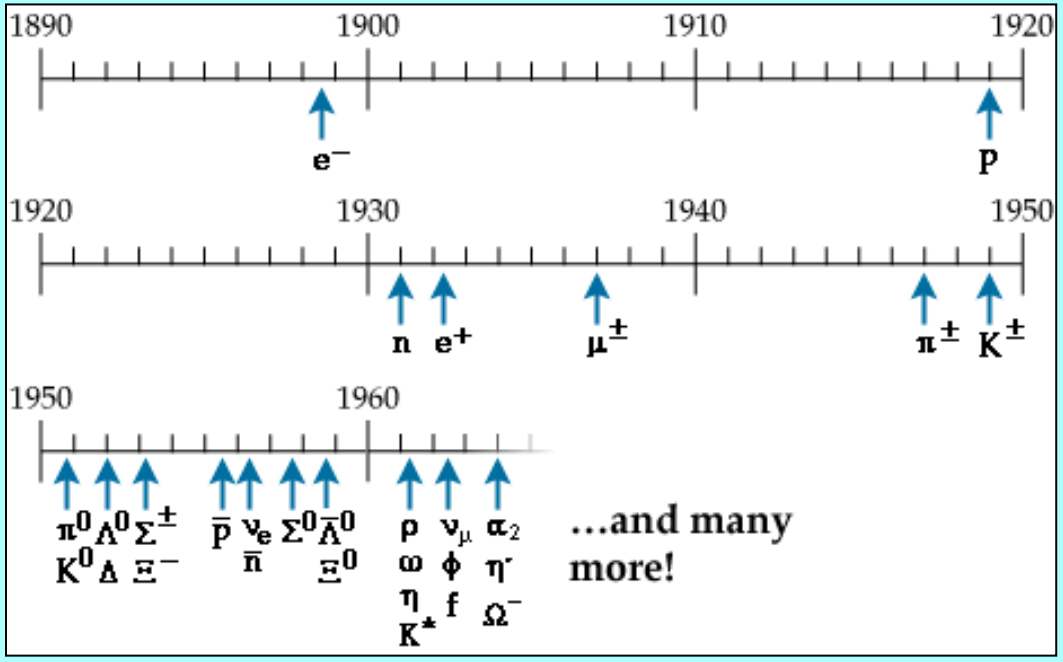
Owen Chamberlain

Emilio Segrè

The Particle Zoo

1960s/70s

Hundreds of 'elementary particles' discovered – ρ, ω, K^*, …, Δ, Ξ, … a real mess!

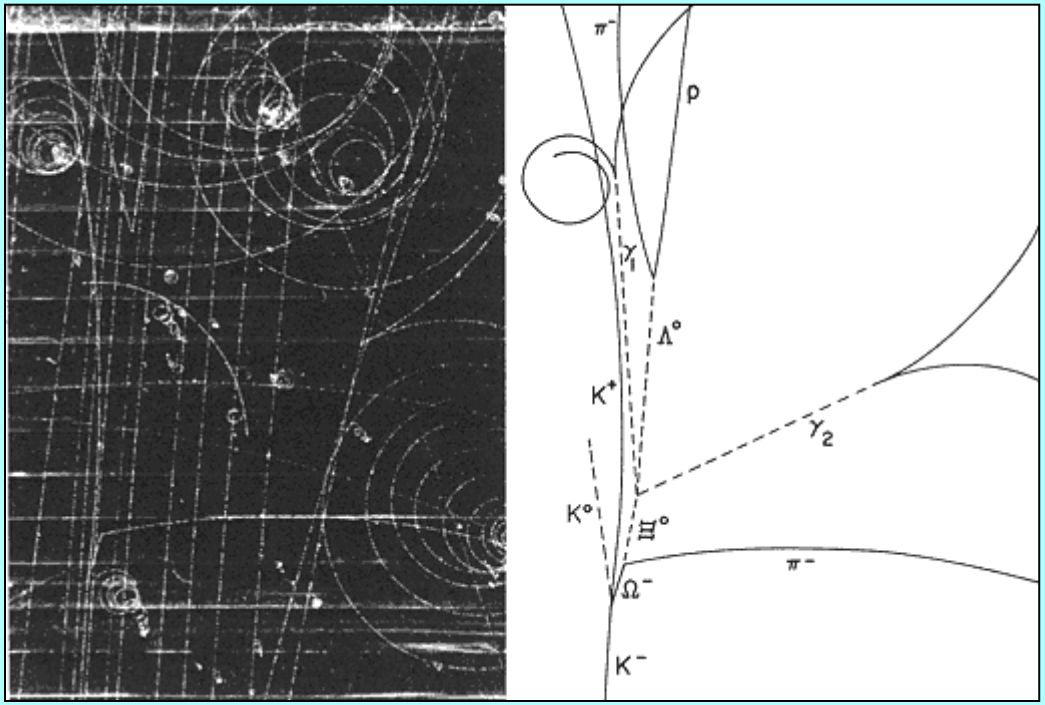


All these particles explained by combinations of more fundamental 'quarks', u, d, s and their anti-quarks.

The Omega Minus

1964

Discovery of the Omega Minus (Ω^-). New quark theory predicted as yet unseen particle with 3 strange quarks. Its discovery at Brookhaven was a great triumph for the new theory and eventually lead to its wide acceptance.



Brookhaven National Laboratory.

Theoretical Advances

1970s
Theory of Strong Interactions – Quantum Chromodynamics, QCD, - quarks interact via exchange of 'gluons'.

Improved understanding of the Weak Interaction – combined with electromagnetism to give 'Electroweak' theory – predicts exchange particles W^+, W^- and Z^0 as carriers of the weak force.

Sheldon Glashow

Abdus Salam

Steven Wineberg

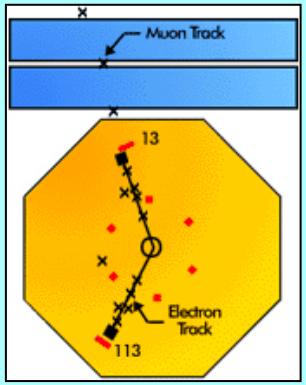
New Quarks and Leptons

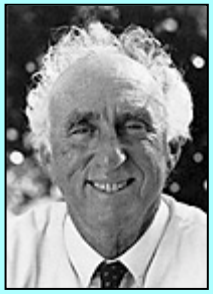
1974
New fourth quark called 'charm' (c) discovered at Stanford and Brookhaven, USA.

Burt Richter

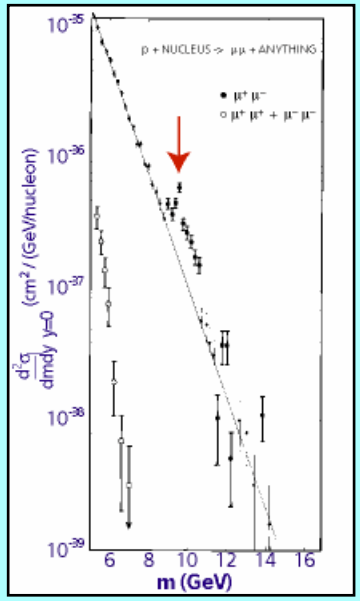
Sam Ting

1975
Third charged lepton tau (τ^-) discovered at Stanford, USA.





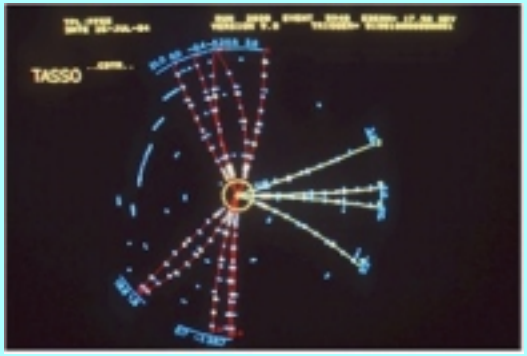
Martin Perl



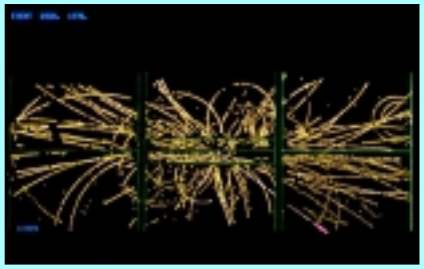
1978
Fifth quark called 'bottom' (b) discovered at Fermilab, USA.

Force Carriers

1979
The gluon, carrier of the Strong Interaction discovered at DESY Hamburg.



1983
The $W^{\pm}$ and Z^0, carriers of the Electroweak Interaction discovered at CERN, Geneva.



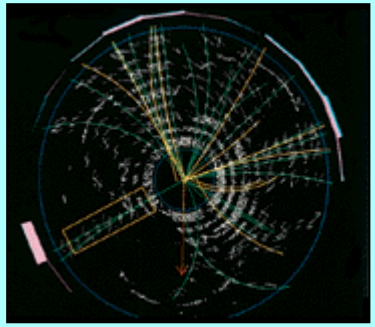
Carlo Rubbia

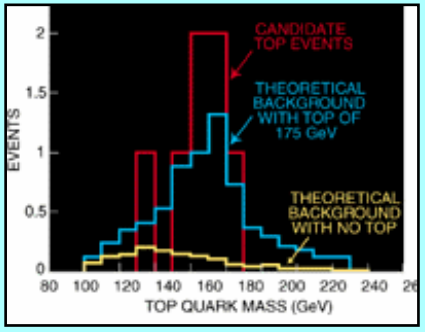
Simon van der Meer

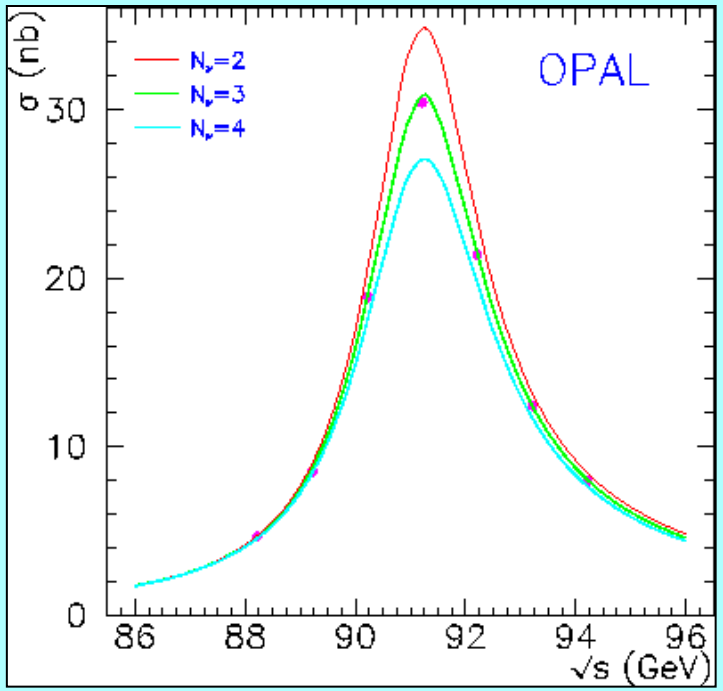
Six Quarks

1990
Number of neutrinos limited to 3
by measurements at LEP, CERN.
Implies a total of 6 quarks.

1995
Sixth quark 'top' (t)
discovered at Fermilab, USA.







Particle Masses

1998
Evidence for neutrino mass from Super-Kamiokande Japan.

2000
Possible evidence for the Higgs Particle from LEP, CERN – not yet confirmed.