

STRUCTURE OF MATTER

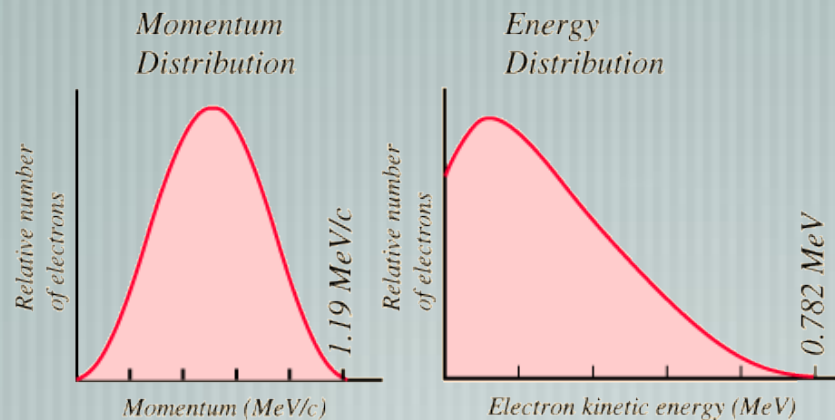
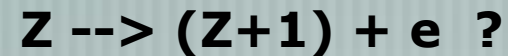
Discoveries and Mysteries

Part 2

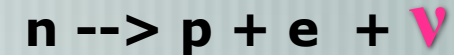
Rolf Landua
CERN

The "Weak Interaction" - What is Radioactivity ?

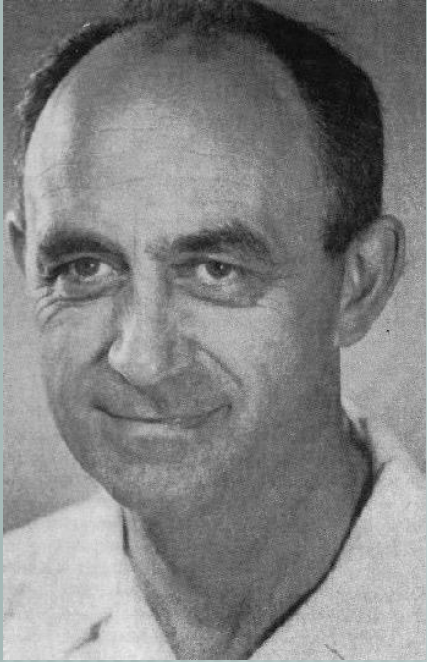
1911: Continuous (?) energy spectrum of 'beta'-rays (electrons) - energy conservation?



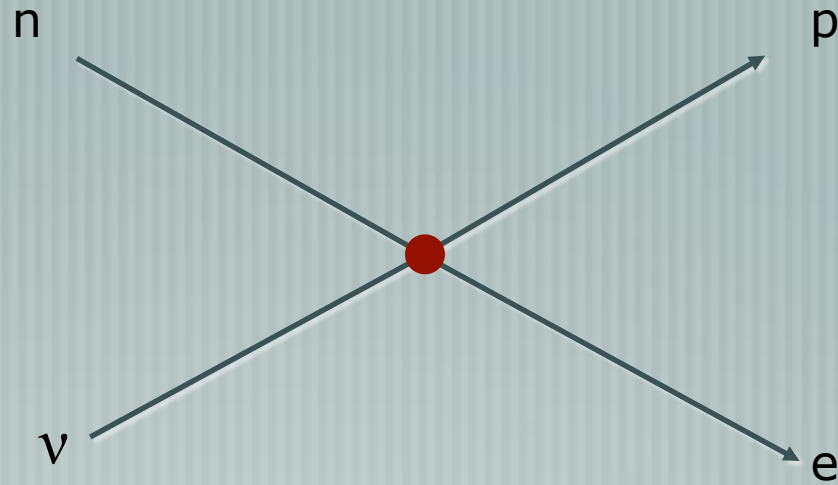
1930: Wolfgang Pauli postulates existence of 'neutrino':



The model of Enrico Fermi : “pointlike interaction”



Enrico Fermi
(1934)

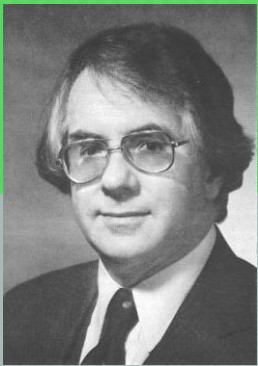


Proposed a **phenomenological** model of weak interaction

Point-like coupling with strength $G_F \sim 10^{-5}$ of e.m. interaction

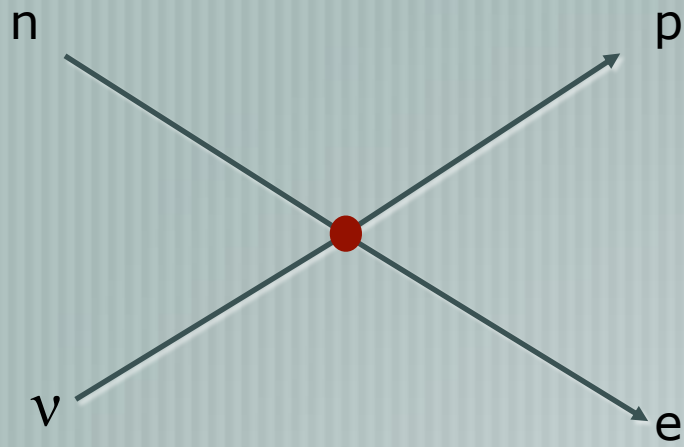
Coupling of two ‘currents’ (proton-neutron / electron-neutrino)

Fermi's model turned out to be inconsistent at $E > 300 \text{ GeV}$



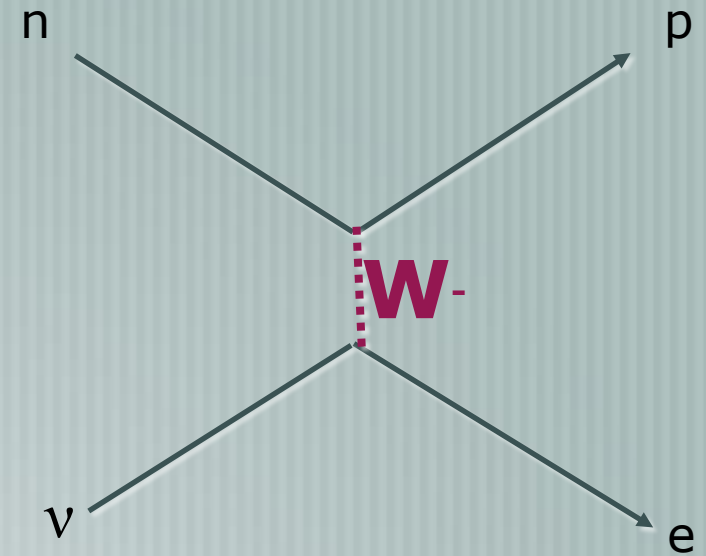
S. Glashow

probability of this reaction $> 100\%$ ($E > 300 \text{ GeV}$)



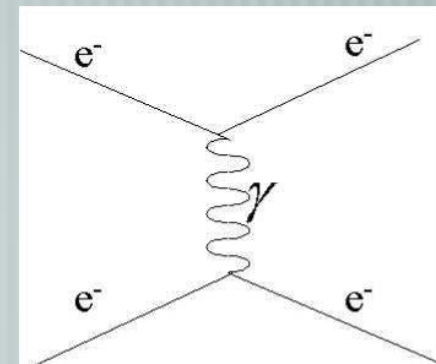
Fermi model

New Idea (1958)

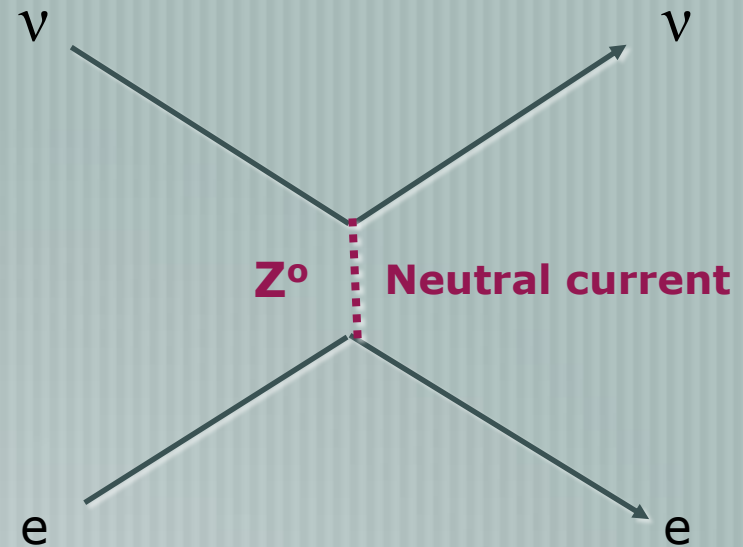
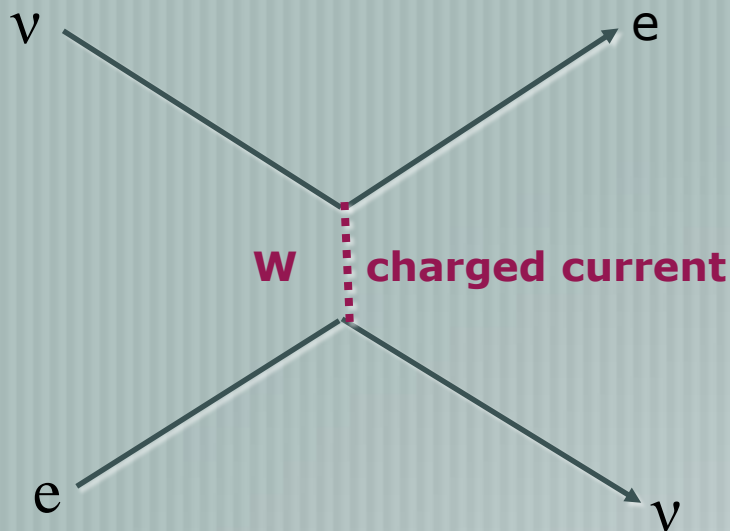


**Weak interaction transmitted by massive vector bosons
(in analogy to photon exchange!)**

**Large mass (80 GeV) explains
short range ($2 \cdot 10^{-18} \text{ m}$) and small cross-sections**



Unification of electromagnetic and weak interaction

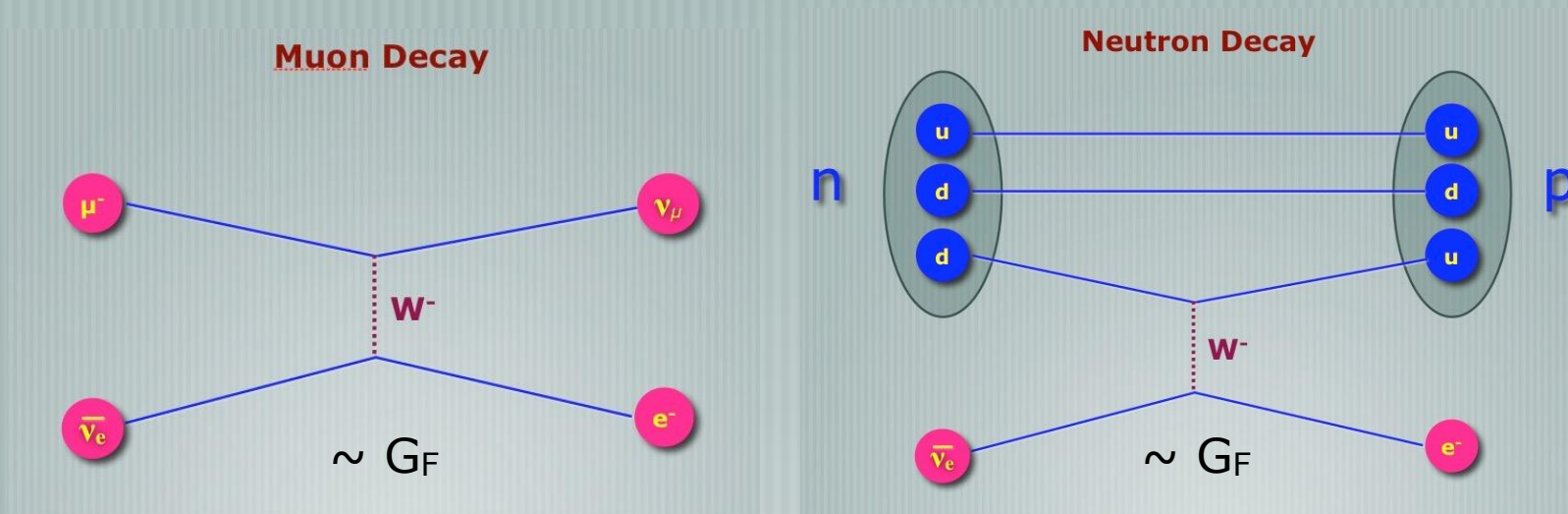


Glashow, Salam, Weinberg (1968) - Electroweak Force

- The electromagnetic and weak interaction are different aspects of the same 'electroweak' force
- All quarks and leptons have a 'weak' charge
- There should be a 'heavy photon' (Z^0) and two charged vector boson (W^\pm) of mass ~ 50 - 100 GeV
- **The W, Z bosons acquire their mass by interacting with the "Higgs field" (1964)**

Fields

Electroweak interaction is the **SAME** for leptons and quarks



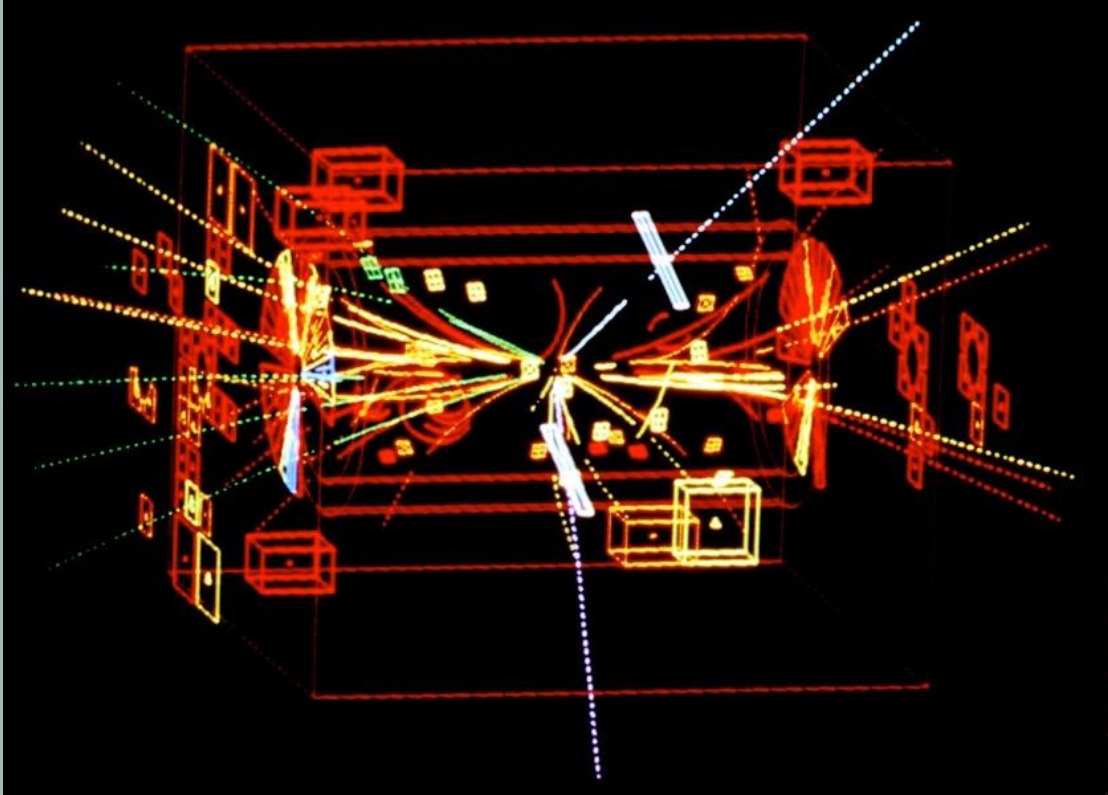
“Universality*” - transmitted by W, Z bosons, same strength!

*Assuming a little bit of ‘quark’ mixing

$$\begin{aligned}d' &= d \cos \theta_c + s \sin \theta_c \\s' &= -d \sin \theta_c + s \cos \theta_c\end{aligned}$$

$\theta_c =$ Cabbibo angle $\sim 20^\circ$

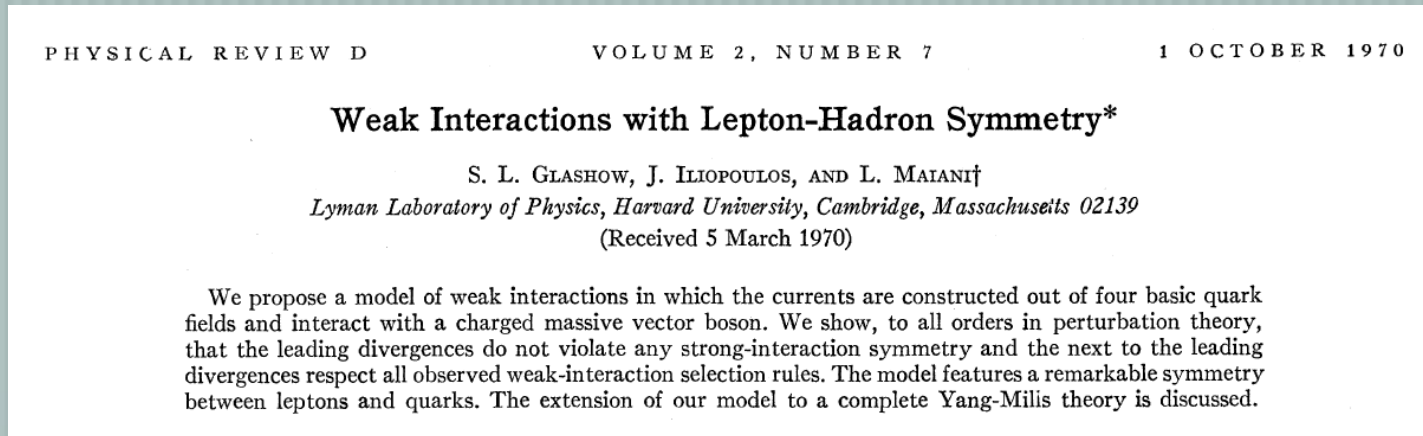
Discovery of the W, Z bosons at CERN (1983)



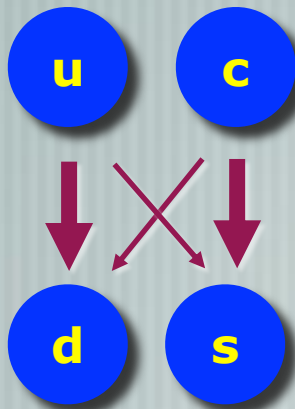
(C. Rubbia, S. van der Meer)

Approaching the 'Standard Model' of today

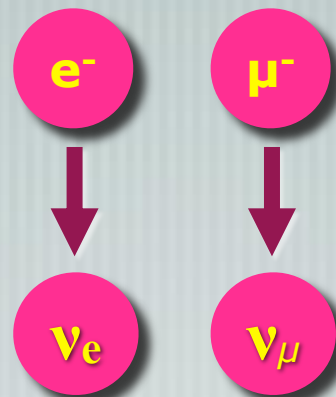
A legendary paper, predicting a new quark (Glashow, Iliopoulos, Maiani)



Quarks



Leptons

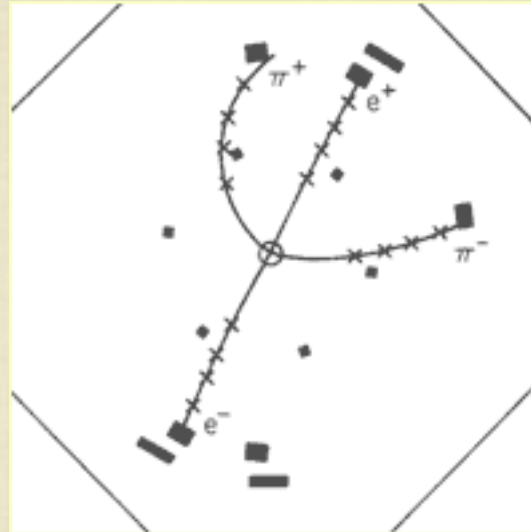


*The "Standard Model"
of 1970*

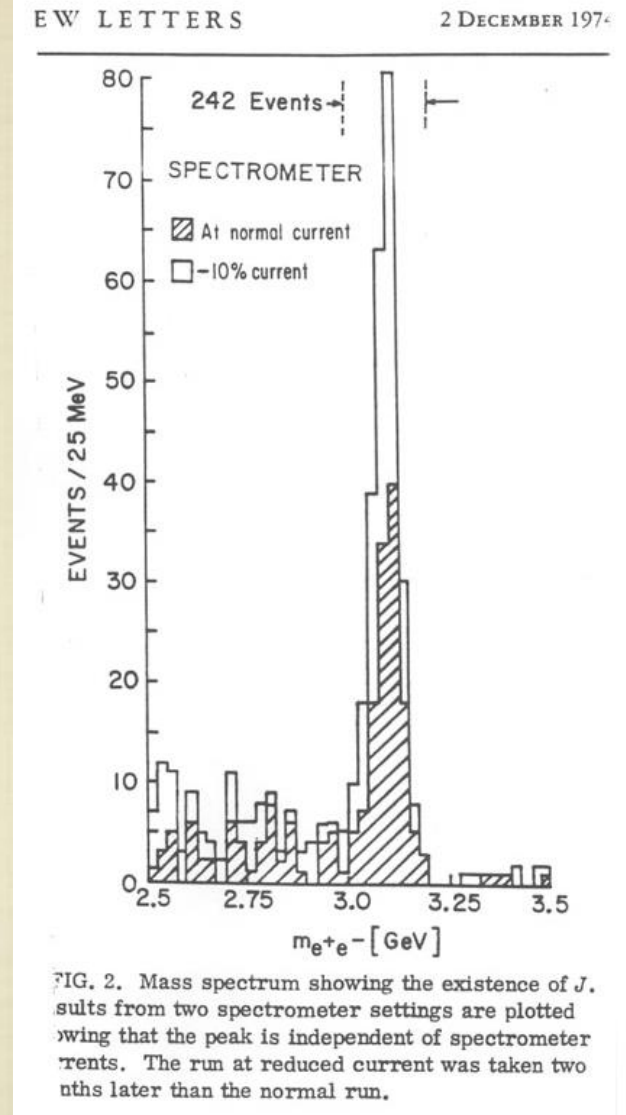
Discovery of the 'charm' quark in 1974

NOVEMBER REVOLUTION (11 November 1974)

'Psi' at SLAC (Burt Richter)
'J' at Brookhaven (Sam Ting)
Compromise: J/Psi



"Extremely" long lifetime ($\sim 10^{-20}$ sec)
Decay only possible through electroweak interaction



But a third family of particles was going to be discovered



Martin Perl

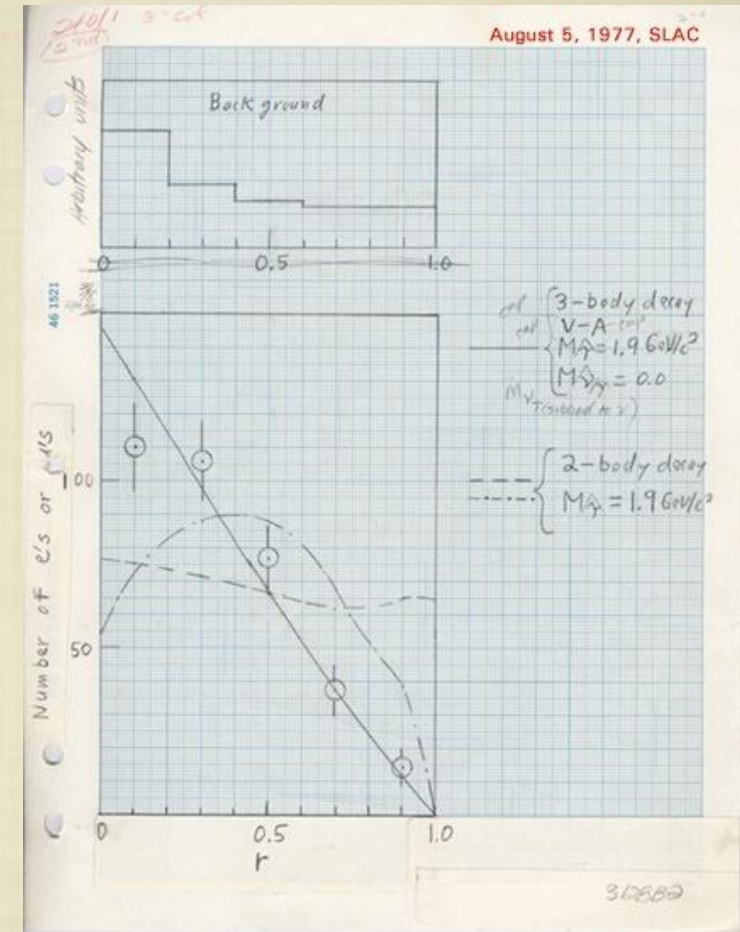
A new 'heavy electron' with $3500 \times m_e$

... who ordered that?



THERE MUST BE A WHOLE NEW FAMILY

**another neutrino (the 'tau neutrino'),
and two more quarks ('top' and 'bottom')**



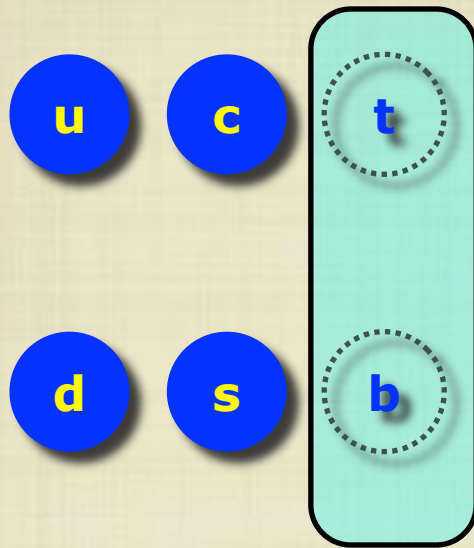
Marty Perl's logbook page

PARTICLE SPECTRUM

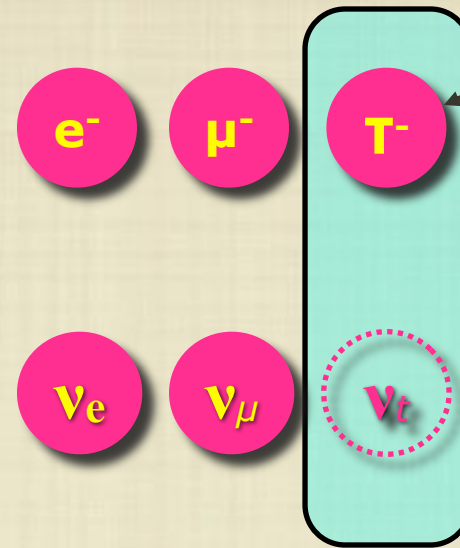
Quarks

1975

The search for the other family members started

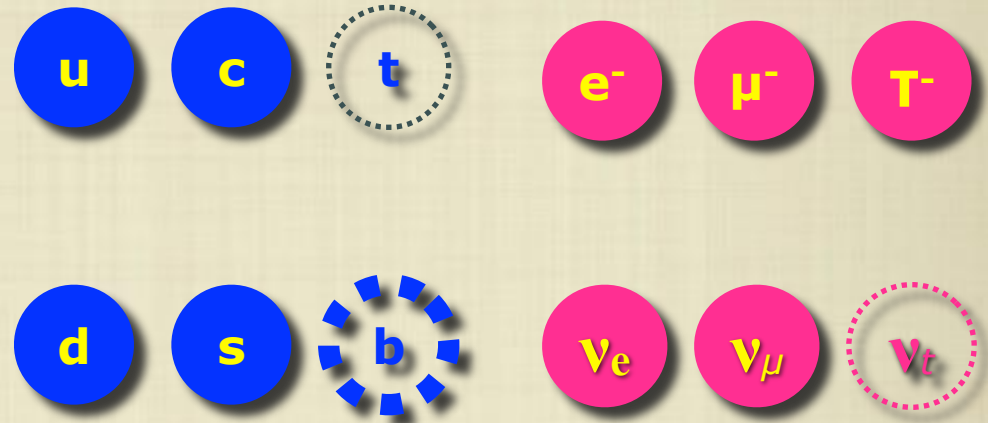
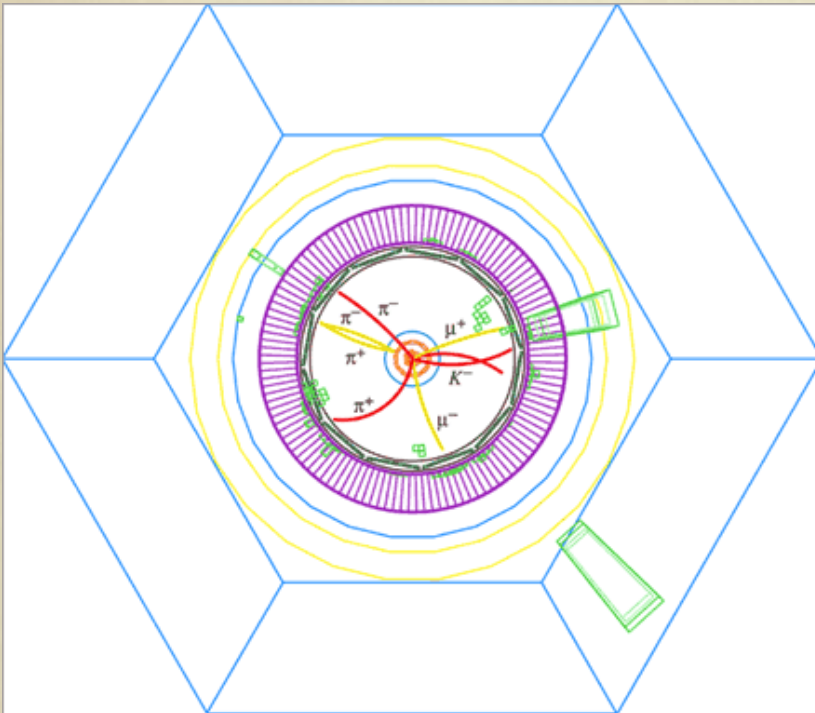


Quarks



Leptons

Discovery of the 'Bottom' Quark (Fermilab)



Quarks

Leptons

In 1977 physicists discovered a new meson called the Upsilon at the Fermi National Accelerator Laboratory.

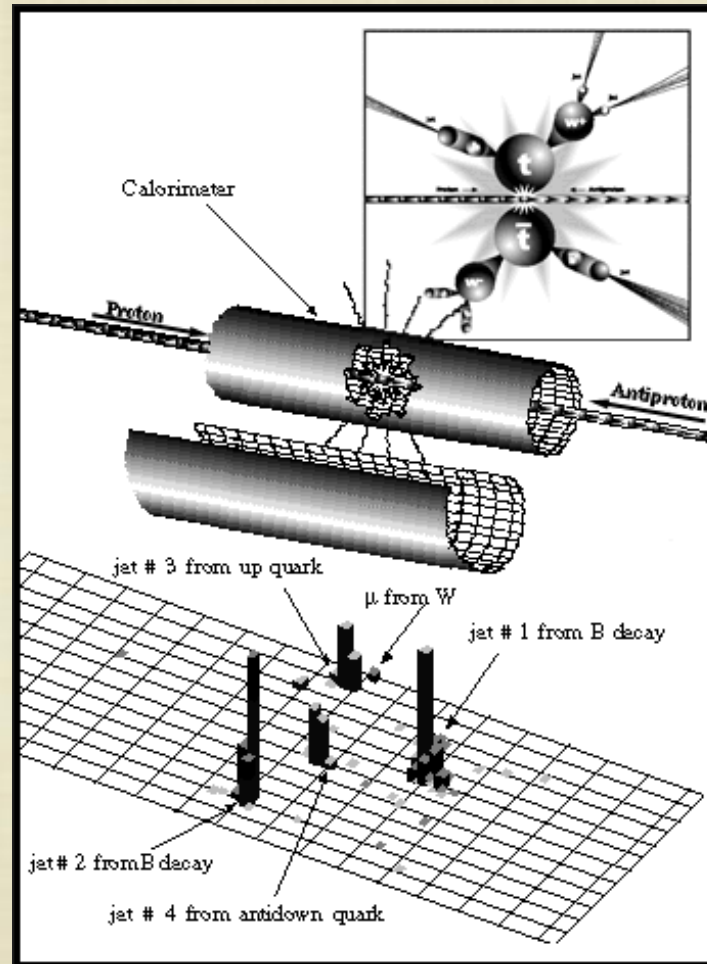
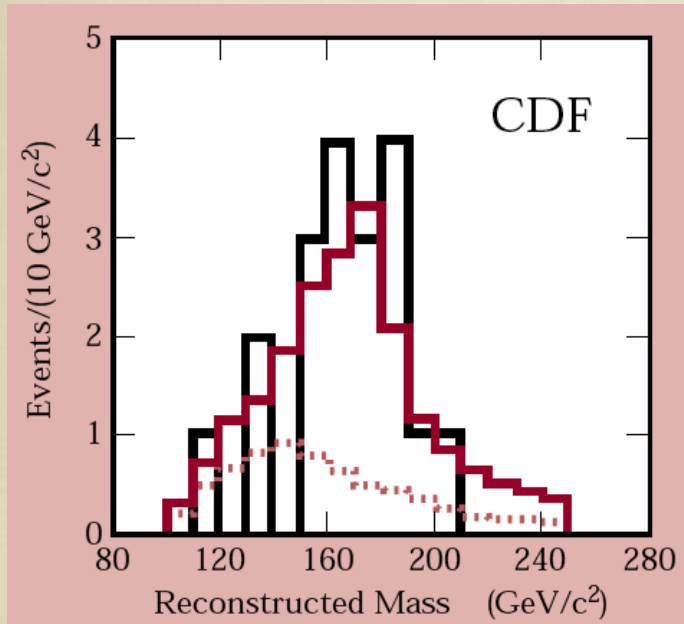
This meson was immediately recognized as being composed of a bottom/anti-bottom quark pair.

The bottom quark had charge $-1/3$ and a mass of roughly 5 GeV.



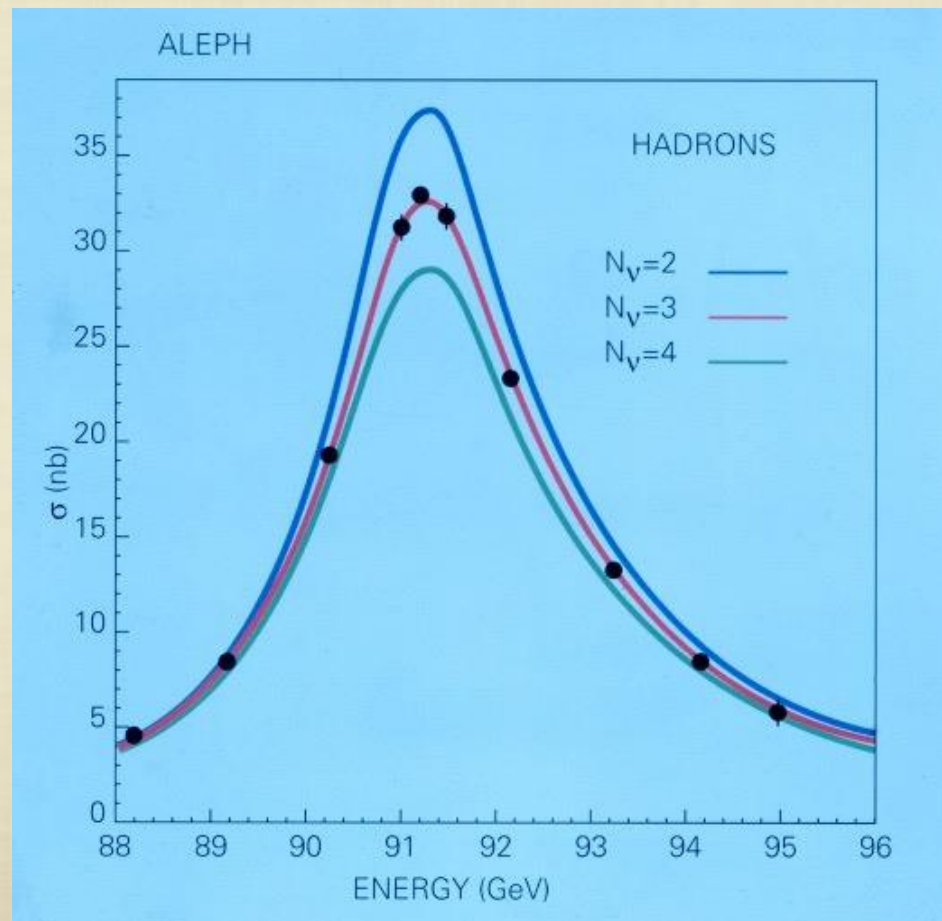
Quarks

Discovery of the 'Top' Quark (Fermilab)



EXACTLY 3 families of particles

LEP measures the decay width of the Z^0 particle



Experiments at accelerators have discovered the whole set of fundamental particles

