Unify Electromagnetic
and Weak Interactions

1. It was suggested by   Schwinger (1956)
                          Glashow (1958) ph.D
                                      Thesis
and was succeeded by

S. Weinberg, PRL 19 (1967)
A. Salam, Proc. of the 8th Nobel Symp. on
          Elementary Particle Theory, (1968)

Note "Renormalizability" was not yet proven by
  ① 't Hooft (1972)

  ② quarks were not included in Weinberg's paper.
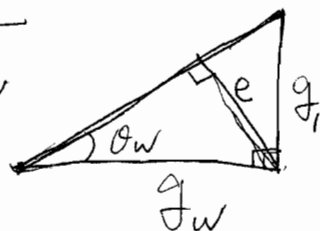
2. Weinberg introduced $SU(2) \times U(1)$
   $\Rightarrow$ require Z^0-boson (with mass M_Z)
        and   Weak mixing angle $\sin \theta_W$
            (or Weinberg's angle)

Predicted:

  ① $M_Z^2 = \dfrac{M_W^2}{\cos^2 \theta_W}$

$$SU(2) \times U(1)$$
$$\uparrow \qquad \uparrow$$
$$g_W \qquad g_1$$

  ② $\sin \theta_W = \dfrac{e}{g_W}$
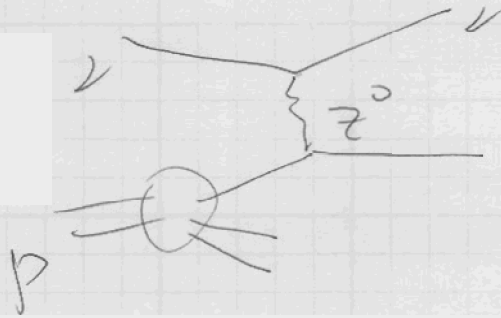
$\cos \theta_W = \dfrac{e}{g_1}$

$\left(\dfrac{1}{e^2} = \dfrac{1}{g_W^2} + \dfrac{1}{g_1^2} \right)$

3. To test $SU(2) \times U(1)$, it is needed to do

$$\nu + p \longrightarrow \nu + \cancel{X}$$
$$\bar{\nu} + p \longrightarrow \bar{\nu} + \cancel{X}$$

via Z^0-boson

$\left(\begin{array}{c} \text{experimentally} \\ \text{Confirmed} \\ \text{in } 1972 \end{array} \right)$

$\left(\begin{array}{c} \text{Neutrino} \\ \text{DIS exp.} \end{array} \right)$
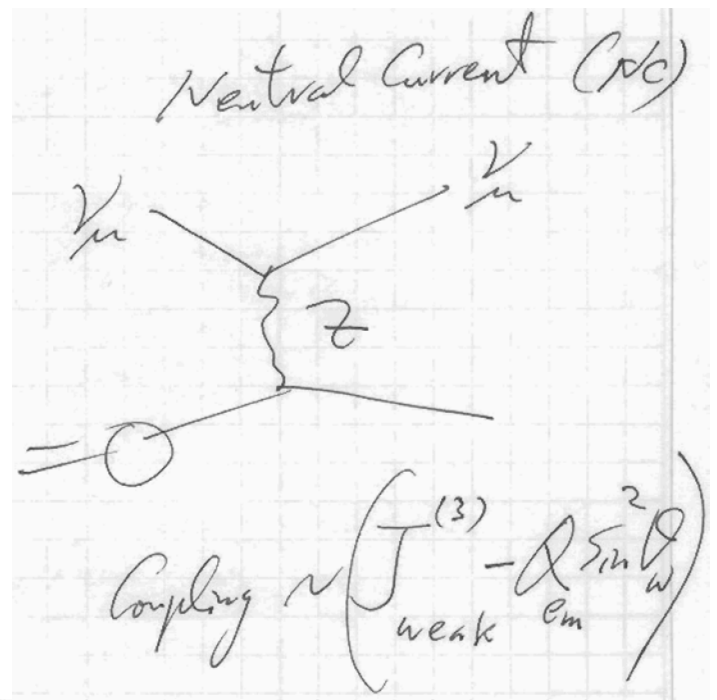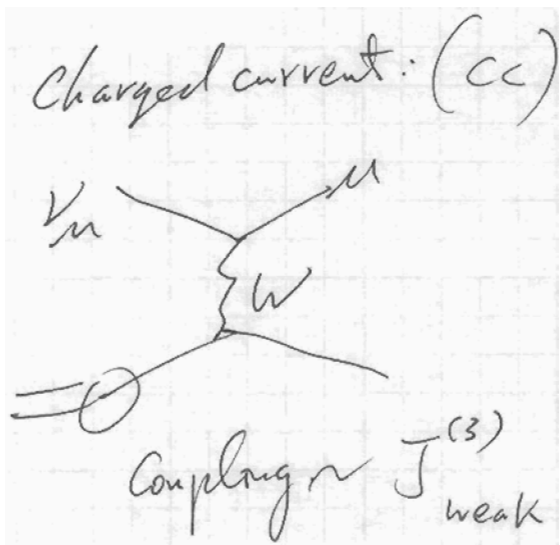
$\Longrightarrow$

① $\sin \theta_w$ was measured

② QCD parton model was confirmed

(quarks ⊕ gluons)

4. ν TeV Experiment (at Fermilab)

$$R^- \equiv \frac{\sigma_{NC}^{\nu_\mu} - \sigma_{NC}^{\bar{\nu}_\mu}}{\sigma_{CC}^{\nu_\mu} - \sigma_{CC}^{\bar{\nu}_\mu}} = \left(\frac{1}{2} + \sin^2\theta_W\right) \cdot \rho^2$$

Charged current: (CC)

Coupling $\sim J^{(3)}_{weak}$

Neutral Current (NC)

Coupling $\sim \left(J^{(3)}_{weak} - Q_{em}\sin^2\theta_W\right)$

$$\left(\text{In the Standard Model,} \quad \rho \equiv \frac{M_W^2}{M_Z^2 \cos^2\theta_W} = 1 \quad \text{at} \right.$$
$$\left. \text{tree level.} \right)$$

4 Fermion Mass

$$\mathcal{L}_e = Y_e \cdot \left(\bar{R} \bar{\phi}_0 L + \bar{L} \phi_0 R \right)$$

Higgs doublet

right-handed fermion

Left-handed fermions

Yukawa coupling

$$\Rightarrow \boxed{m_e = \frac{Y_e \cdot v}{\sqrt{2}}}$$

depends on the unknown Y_e

$\Rightarrow m_e$ can not be predicted by the model.