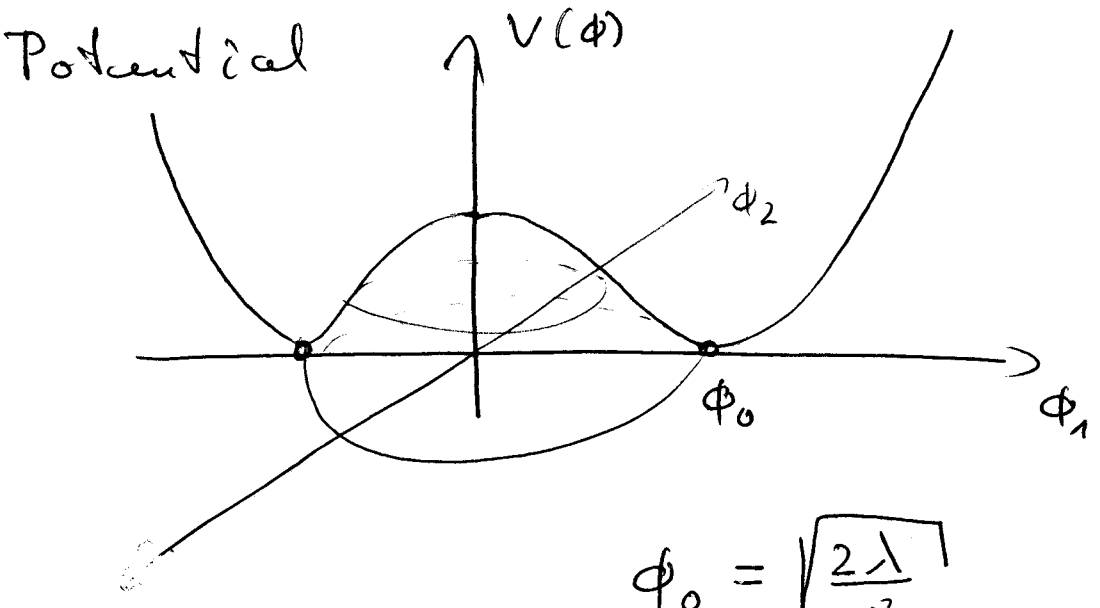
8.2 Spontaneous symmetry breaking

The gauge bosons of the weak force are massive, $Z, W^{\pm} \sim 10^2$ GeV.

Mass terms for the gauge fields <u>break</u> gauge invariance!! Way out: spont. symm. breaking, Higgs mechanism

$$S_{Higgs}[A_\nu, \phi] = \int \Big((D_\nu \phi)^\dagger (D_\nu \phi) + \underbrace{\mu^2 \phi^\dagger \phi - \lambda (\phi^\dagger \phi)^2}_{-V(\phi)} \Big) \qquad (8.19)$$

with $A_\nu \in u(1) \times su(2)$



$$\phi_0 = \sqrt{\frac{2\lambda}{\mu^2}}$$

The minimum is at a non-trivial field expectation value, e.g. $\langle \phi \rangle = \phi_0$

[Strictly speaking this is valid for

$$V(\phi) = \lambda (\phi^\dagger \phi)^2 - \mu^2 \phi^\dagger \phi - \varepsilon \phi_0 \qquad (8.20)$$

with $\varepsilon \to 0$]

Expanding about ϕ_0 : $\phi = \phi_0 + \delta\phi$

leads to ($\partial_\nu \phi_0 = 0$)

$$(D_\nu \phi)^\dagger (D^\nu \phi) = g^2 A_\nu \phi_0 A^\nu \phi_0 + \delta\phi\text{-terms}$$

mass-term for gauge field

(8.21)

Matter sector:

$$h \bar{\Psi} \phi \Psi + h.c. = 2h \bar{\Psi} \phi_0 \Psi + \delta\phi\text{-terms}$$

(8.22)

mass term for fermions

⇒ Higgs mechanism provides masses for gauge bosons & quarks, leptons

Remarks

In the Standard model only the left-handed spinors transform under the weak gauge group: $\Psi_L \to U \Psi_L$

$$\Psi_R \to \Psi_R$$

$$\phi \to U\phi$$

Hence, gauge-invariant mass terms have the form

$$\Psi_R \, \phi^+ \, \Psi_L + \text{h.c.}$$

[see e.g. Standard model lecture script 5.2 Higgs sector]