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The Standard Model of Particle Physics - SoSe 2010 Assignment 5

Due June 24

1 Total Z-width Γ_Z

Estimate the total width of the Z-boson in the Standard Model. Please consider that the hadronic width Γ_{had} is the sum of the partial widths of the decays into the possible quark species,

$$\Gamma_{had} = \sum_q \Gamma_{q\bar{q}}$$

In the calculation of the partial widths $\Gamma_{q\bar{q}}$ the non-observable color-charge of the the quarks has to be considered and leads to an increase of the partial widths by the color factor $N_C = 3$. For the calculation use $M_Z = 91.188$ GeV and $\sin^2\theta_w = 0.231$ Compare your result to the measurement by LEP, $\Gamma_Z = 2.4952 \pm 0.0023$ GeV.

2 Forward-backward asymmetry for $b\bar{b}$ and $c\bar{c}$ events

For events $e^+e^- \to$ hadrons with a two-jet signature the jet direction can be used to approximate the original quark direction. This allows to measure the angular distribution $d\sigma/d|\cos\theta|$ of the events. Moreover, for events with b and c-quark it is possible to determine the flavor which allows a determination of the forward-backward assymetry separately for $b\bar{b}$ and $c\bar{c}$ events.
What is the Standard Model prediction for the $b\bar{b}$ and $c\bar{c}$ forward-backward asymmetries $A_{FB}^{b\bar{b}}$ and $A_{FB}^{c\bar{c}}$ at the Z-pole ($\sqrt{s} = M_Z$)?

3 Weak and electromagnetic coupling constants

Show that in the Standard Model the tree-level relation between the Fermi constant G_F and the electromagnetic fine-structure constant α is given by:

$$G_F = \frac{\pi\alpha}{\sqrt{2}M_W^2 \sin^2\theta_w}$$

4 Effective couplings and electro-weak mixing angle

The LEP experiments have determined the effective couplings of charged leptons,

$$\bar{g}_A = \sqrt{\bar{\rho}}\, T_3 \quad \text{and} \quad \bar{g}_A = \sqrt{\bar{\rho}}\, (T_3 - 2Q \sin^2\theta_{eff})$$

to be $\bar{g}_A = -0.50123 \pm 0.00026$ and $\bar{g}_V = -0.03783 \pm 0.00041$. The term $\sin^2\theta_{eff}$ includes radiative corrections and is different from the tree-level quantity $\sin^2\theta_w$. Determine the effective weak mixing-angle and compare it to the tree-level definition of $\sin\theta_w$,

$$\sin^2\theta_w = 1 - \frac{M_W^2}{M_Z^2}$$

with $M_W = (80.399 \pm 0.023$ GeV and $M_Z = (91.1875 \pm 0.0021)$ GeV (values from direct measurements).

Remark: At tree-level the ρ parameter is defined as

$$\rho = \frac{M_W^2}{M_Z^2 \cos^2\theta_w}$$

and equal to 1. Higher order corrections leads to a deviation from the tree-level relation. The „effective“ value which is observed is $\bar{\rho} = 1.0050 \pm 0.0010$.

5 W decays

The leptonic as well as the hadronic decays of the W bosons were intensively studied at LEP-2. Estimate the leptonic and hadronic branching ratios of the W boson.

6 Parameter of the electroweak Standard Model

Give a complete set of independent parameters of the elctro-weak Standard Model. How many parameters are necessary? Discuss different possible choices.