Physikalisches Institut
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Theoretische Physik

Exercise Sheet 1
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Exercises Quantum Field Theory II

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http://www.th.physik.uni-bonn.de/klemm/qft2ws1516/

–Homework–

1 Higgs corrections to $g-2$ (15 pts.)

Any particle that couples to the electron can produce a correction to the electron-photon form factors and, in particular, a correction to $g-2$. Because the electron $g-2$ agrees with QED to high accuracy, these corrections allow us to constrain the properties of hypothetical new particles.

1. To build up courage for what follows we start with something simple. Prove the Gordon identity

$$\bar{u}(p')\gamma^\mu u(p) = \bar{u}(p')\left[\frac{p'^\mu + p^\mu}{2m} + \frac{i\sigma^{\mu\nu q_\nu}}{2m}\right] u(p). \tag{1}$$

   3 pts.

2. The unified theory of weak and electromagnetic interactions contains a scalar particle h called the *Higgs boson*, which couples to the electron according to

$$H_{int} = \int d^3x\, \lambda h \bar{\psi}\psi. \tag{2}$$

   Compute the contribution of a virtual Higgs boson to the electron $g-2$, in terms of the coupling constant λ and the mass m_h of the Higgs boson. *Hint: After you have used the Gordon identity to identify $F_1(q^2)$ and $F_2(q^2)$ don't try to evaluate the former. You only need $F_2(q^2)$ to calculate $g-2$.* **10 pts.**

3. QED accounts extremely well for the electron's anomalous magnetic moment. If $a = (g-2)/2$,

$$|a_{expt.} - a_{QED}| < 1 \times 10^{-10}. \tag{3}$$

   What limits does this place on λ and m_h? The Higgs boson has recently been found at the LHC and the coupling and mass have been determined to be $\lambda \approx 2.1 \times 10^{-6}$ and $m_h \approx 126\,\text{GeV}$ respectively. Show that these values are not excluded by the experimental bounds on a. **2 pts.**