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Standard Model **Homework 4** **Date: 14.07.2022**

Exercice 1: Standard Model: interactions and conservation laws

Are the following decays permitted in the Standard Model? If not, why?

1. $n \to p\mu^-\bar{\nu}_\mu$
2. $\mu^- \to e^-e^-e^+$
3. $n \to p\nu_e\bar{\nu}_e$
4. $p \to e^+\pi^0$
5. $\pi^0 \to \gamma\gamma$
6. $\tau^- \to \mu^-\gamma$
7. $K^0 \to \mu^+e^-$
8. $\mu^- \to \pi^-\nu_\mu$
9. $\mu \to e\gamma$
10. $\mu \to e\nu_e\bar{\nu}_\mu$

Exercice 2: BSM proton decay

With the particle content of the SM, baryon number is an accidental symmetry when restricting to renormalisable interactions. What is the mass dimension of the interactions that can induce a decay of the proton? Given that the current experimental lower bound on the lifetime of the proton in 10^{34} years, find the lower bound on the scale of these interactions.

Exercice 3: Goldstone equivalence theorem

a) Draw the Feynman diagram for the decay of the top quark, $t \to bW$.
b) Neglecting the bottom mass, calculate, in the unitary gauge, the decay rates for $t \to bW_T^+$ and $t \to bW_L^+$. Reproduce the latter result using the equivalence theorem, i.e. by computing the $t \to b\phi^+$, where ϕ^+ is the would-be Goldstone boson.
c) Draw the Feynman diagram for the Higgs decay into a pair of W gauge bosons.
d) In the heavy Higgs mass limit, compute, in the unitary gauge, the decay widths of $h \to W_T^+W_T^-$ and $h \to W_L^+W_L^-$. Reproduce the latter result using the equivalence theorem, i.e. by computing the $h \to \phi^+\phi^-$, where $\phi^\pm$ are the would-be Goldstone bosons.