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Übungen zu Teilchenphysik I

Wintersemester 2024/25

Exercise 7

To be worked on until January 30, 2025

Top quark pair production

The top quark was discovered 1995 at the Tevatron collider¹² as the last and heaviest quark in the standard model of particle physics. Using data collected at the LHC, we will reconstruct top quarks from semi-leptonic decays and measure the top quark mass from a template fit.

At the LHC, top quarks are mostly produced in pairs of a quark and an antiquark ($t\bar{t}$). These quarks decay under the weak interaction almost exclusively into a W boson and a bottom quark. W bosons decay hadronically in about 2/3 of all cases into two quarks and in about 1/3 of all cases into a charged lepton and the corresponding neutrino. Combining these decays, there are three possibilities for a $t\bar{t}$ pair to decay:

- **All-hadronic:** both W bosons decay into quarks.
- **Dileptonic:** both W bosons decay into a charged lepton and a neutrino.
- **Semileptonic:** one W boson decays into quarks and the other decays into a charged lepton and a neutrino.

¹<https://doi.org/10.1103/PhysRevLett.74.2626>

²<https://doi.org/10.1103/PhysRevLett.74.2632>

In this exercise we will focus on the semileptonic channel, more precisely the $\mu + \text{jets}$ channel. A Feynman diagram of such a process is shown in Fig 1. This channel has the advantage of a high branching ratio compared to the dileptonic channel and a small background contribution compared to the all-hadronic channel.

The tasks of this exercise are outlined in a Jupyter Notebook, which can be found in the `Exercise07` folder on the [tp1_forstudents](#) repository. The standard `Datenanalyse` container on the [jupyter-machine](#) is sufficient for the exercise.

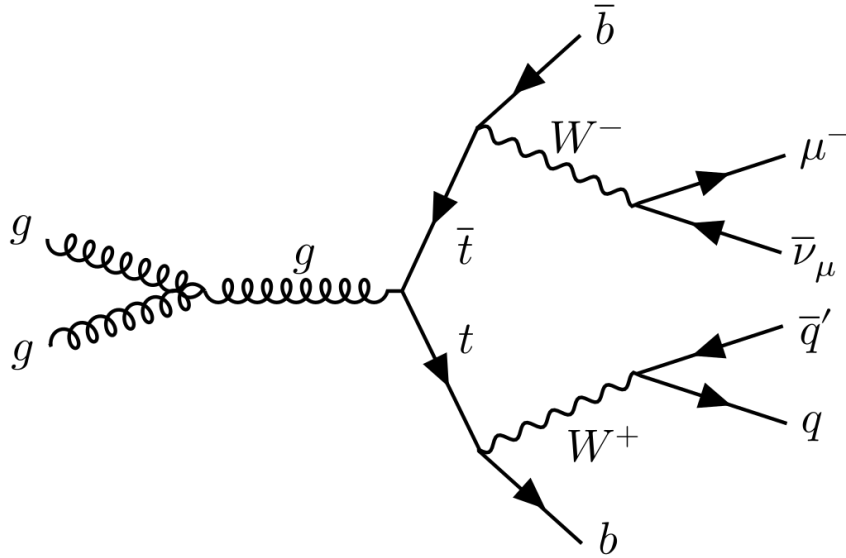


Figure 1: Feynman diagram of top quark pair production including final-state decays. One of the W bosons decays into a muon and a muon antineutrino, while the other W boson decays into a quark and an antiquark.