Flavor Physics – Exercise Sheet 2 – SomSem 2014

Discussion: 09/05 during the tutorial

Exercise 1: Cabibbo-Matrix

Historically, the quark mixing in the case of two generations was described by the 2×2 dimensional Cabibbo-matrix.

- How many free parameters has this matrix?
- Why can't there be any CP violation in the case of two quark generations?
- Considering unitarity, how should the Cabibbo-matrix look like?

Exercise 2: Helicity suppression

The theoretical branching fraction for the decay $B_s \to \mu^+\mu^-$ is 3.2×10^{-9} (see A.Buras et al. in arXiv:1208.0934).

- Use the argument of the helicity suppression of the matrix element in the pion decay ($\propto m_\ell$) to estimate the branching fraction $B_s \to \tau^+\tau^-$.
- Estimate the branching fraction of $B_d \to \mu^+\mu^-$. For simplicity assume equal masses as well as equal decay constants for the two B mesons B_s and B_d.

Exercise 3: Tau-decays

Tau leptons decay to leptons as well as to hadrons and present an excellent system to study the properties of the weak and strong interaction. In the case of hadronic decays, note that the lightest "charmed" hadron (D meson) already has a mass of 1869 MeV/c^2 larger than the mass of the tau (1.777 GeV/c^2).

- Draw the Feynman graphs (quark level) for the possible leptonic and hadronic τ^- decays. In case of the decays to quarks add the coupling strength described by the CKM matrix elements to the quark vertices of the Feynman graphs.
- Neglect the mass of the decay products and estimate the tau branching fractions to electrons, muons and to hadrons. Hint: Consider the different colors of the quarks and note that $|V_{ud}|^2 + |V_{us}|^2 \approx 1$
- Express the tau lifetime as function of the partial decay width of the tau to electrons, $\Gamma(\tau^- \to e^-\bar{\nu}_e\nu_\tau)$, and use the muon lifetime (2.2μs) to estimate the lifetime of the tau lepton. Hint: Relate the muon decay width $\Gamma(\mu^- \to e^-\bar{\nu}_e\nu_\mu)$ calculated in the lecture to the partial decay width of the tau to electrons $\Gamma(\tau^- \to e^-\bar{\nu}_e\nu_\tau)$.