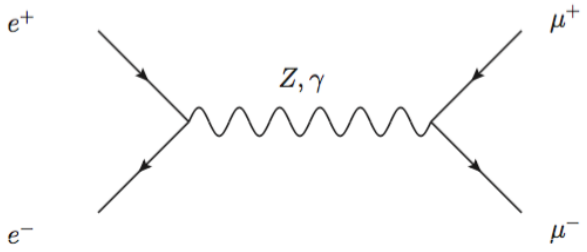
Exercises for Theoretical Particle Physics I

Björn Garbrecht
Dario Gueter
Juraj Klarić
SS 2017
Sheet 6
To be handed back on June 29nd

The width of the Z-boson cannot be measured in a classic decay experiment, but has to be inferred from the cross-section of processes where the Z-boson appears as intermediate virtual state. One of these processes is $e^+e^- \to \mu^+\mu^-$.

Problem 1: Channels for $e^+e^- \to \mu^+\mu^-$ — 1 point

The process $e^+e^- \to \mu^+\mu^-$ is mediated by the s-channel diagram.:



The intermediate particle can be a photon, a Z-boson or a Higgs. Argue why we can neglect the Higgs channel in a first approximation?

Problem 2: Matrix elements for $e^+e^- \to \mu^+\mu^-$ — 6 points

Calculate the matrix elements for $e^+e^- \to \mu^+\mu^-$ with intermediate photon γ and Z-boson. Use the finite width Z-propagator

$$\frac{-\mathrm{i}}{p^2 - m_Z^2 + \mathrm{i} m_Z \Gamma_Z} \left(g^{\mu\nu} - \frac{p^\mu p^\nu}{p^2 - \xi m_Z^2}(1-\xi) \right) ,$$

in unitary gauge ($\xi \to \infty$).

Problem 3: Total cross section for $e^+e^- \to \mu^+\mu^-$ — 9 points

Using the two matrix elements, calculate the total cross section for $e^+e^- \to \mu^+\mu^-$ for the following three cases:

- only photons are exchanged ,
- only Z-bosons are exchanged ,
- both photons and Z are exchanged .

Plot the three contributions for energies between 10 GeV and 200 GeV (Use for example Mathematica and print out the plots). What effect do quantum interferences have?