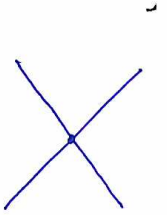
NTNU Trondheim, Institutt for fysikk

Home exam FY3403 Particle Physics

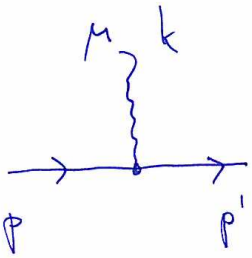
1. Large Hadron Collider.
Read the section 25 and 26 of the Particle Data Review (http://pdg.lbl.gov). The connection between the event rate, luminosity and cross section is $R = \mathcal{L}\sigma$. Assuming LHC is running according its design parameters, what is i) the total event rate (given by $\sigma_{\text{inel}}(pp)$), ii) the rate of "new physics" events estimated by setting $\sigma(\text{"}new\text{"}) \sim \alpha_w^2/M^2$ with $M = 300\,\text{GeV}$ and $\alpha_w = g^2/(4\pi)$, iii) the total kinetic energy in the beam?

2. Compton scattering in scalar QED.
Consider Compton scattering $\phi(p) + \gamma(k) \to \phi(p') + \gamma(k')$ between a scalar particle ϕ with mass m and a photon.
a. Draw all Feynman diagrams and write down the matrix element $\mathcal{M}_{fi}$ of this process at lowest order perturbation theory. Calculate the differential and total cross section σ. (Hint: The matrix element simplifies to $|\mathcal{M}|^2 = 4e^4(\varepsilon' \cdot \varepsilon)^2$ choosing a suitable frame and polarization vectors.)
b. Gauge invariance (or current conservation) implies that matrix elements are invariant under gauge transformations, $\varepsilon_i^\mu \to \varepsilon_i^\mu + \lambda k_i^\mu$, where ε_i are the polarization vectors, k_i^μ the momentum vectors of photons and $\lambda \in \mathbb{R}$. In particular, the matrix element vanishes, $\mathcal{M}_{fi} = 0$, for the replacement $\varepsilon_i^\mu \to k_i^\mu$. Show that the matrix element is gauge invariant only when the vertex c is included.

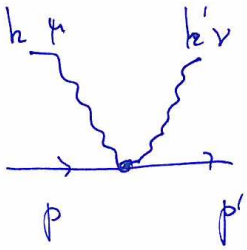
3. Antineutrino-electron scattering in the Fermi theory.
Consider antineutrino-electron scattering $\bar{\nu}_e(k) + e^-(p) \to \bar{\nu}_e(k') + e^-(p')$ via the charged current in the Fermi theory.
a. Write down the Feynman amplitude $\mathcal{M}$ of this process, and sum/average the squared matrix element $|\mathcal{M}|^2$.
b. Calculate the differential cross section $\mathrm{d}\sigma/d\Omega$ and the total cross section σ.
c. Explain why $\mathrm{d}\sigma/d\Omega$ vanishes for $\vartheta = \pi$.



$-i\lambda$

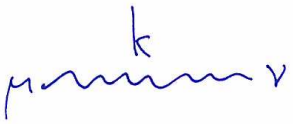


$-ie(p_\mu + p'_\mu)$



$2ie^2 g_{\mu\nu}$

$$\frac{i}{k^2 - m^2 + i\varepsilon}$$



$$\frac{-i g_{\mu\nu}}{k^2 + i\varepsilon}$$

(Feynman gauge)

[N.B.: scalar particles solid line for better visibility]