

Elementary Particle Physics: Assignment # 8

Due April 16 Before class

You are looking for a heavy 4th-generation fermion F with electric charge -1 and mass m_F which can be pair produced in quark-antiquark collisions $q\bar{q} \rightarrow F\bar{F}$ via electromagnetic interactions.

QED predicts the fundamental cross section to be

$$\sigma_{q\bar{q} \rightarrow F\bar{F}}(\hat{s}) \simeq \frac{4\pi\alpha^2 e_q^2}{3\hat{s}} \sqrt{1 - 4m_F^2/\hat{s}} \quad (1)$$

where e_q is the charge of the quark.

Question: Compute the cross section $pp \rightarrow F\bar{F}X$ in nb (nb= 10^{-37} m²) and for $p\bar{p} \rightarrow F\bar{F}X$ for $\sqrt{s} = 7$ TeV (center of mass energy of the hadron-hadron collision) for masses $M=100, 1000$ GeV. Suppose that the up and down valence quark distribution in the proton are given by $u_v(x) = 2d_v(x) = 6(1-x)^2$ and that all the sea are $u_s(x) = \bar{u}_s(x) = d_s(x) = \bar{d}_s(x) = (1-x)^3/(4x)$. Neglect the contribution of the strange quark. Discuss the difference between the result in pp and $p\bar{p}$

Hint: You are going to need to evaluate first some integrals which can be done analitically. And then a second integral has to be done numerically (for example with Mathematica)

Here are the answers of the first integrals (you may also check them):

$$\begin{aligned} I_1(\tau) &= \int_{\tau}^1 dx \frac{1}{x^3} (1-x)^2 (x-\tau)^2 = 3(\tau^2 - 1) - (\tau^2 + 4\tau + 1) \ln(\tau) \\ I_2(\tau) &= \int_{\tau}^1 dx \frac{1}{x^4} (1-x)^3 (x-\tau)^2 = \frac{1}{\tau} \int_{\tau}^1 dx \frac{1}{x^3} (1-x)^2 (x-\tau)^3 = \\ &\quad \frac{1}{3}(-10\tau^2 - 9\tau + \frac{1}{\tau} + 18) + (\tau^2 + 6\tau + 3) \ln(\tau) \\ I_3(\tau) &= \int_{\tau}^1 dx \frac{1}{x^4} (1-x)^3 (x-\tau)^3 = \frac{11}{3}(\tau^3 - 1) + 9\tau^2 - (\tau^3 + 9\tau^2 + 9\tau + 1) \ln(\tau) \end{aligned}$$