Elementary Particle Physics: Assignment # 9

Due Thursday April 11 Before class

Suppose that you are looking for a heavy 4th-generation fermion F with electric charge -1 and mass M which can be pair produced in quark-antiquark collisions $q_i\bar{q}_i \to F\bar{F}$ via electromagnetic interactions.

1 Show that QED predicts the fundamental cross section to be

$$\sigma(\hat{s}) = \frac{4\pi\alpha^2}{3\hat{s}}\sqrt{1 - 4m_F^2/\hat{s}} \tag{1}$$

2 Compute the cross section $pp \to F\bar{F}X$ in nb (nanobarns) and for $p\bar{p} \to F\bar{F}X$ 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 $u_s(x) = \bar{u}_s(x) = d_s(x) = \bar{u}_s(x) = (1-x)^3/(4x)$. 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):

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