M2 NPAC - Particle physics (2019-2020)

Exercise sheet № 7 - W boson properties

1 W-boson mass measurement

We consider the production of the W boson in p-$\overline{p}$ collisions, with the proton beam oriented along the $\vec{z}$ axis. We assume that at first order the W boson is emitted with $p_T^W \approx 0$.

1. We first consider the hadronic decay of the W. While the W-boson invariant mass can be fully reconstructed, give at least two reasons which makes the measruement in this channel extremely challenging.

2. We then consider the leptonic decay $W \to \ell\nu$ with $\ell \equiv e, \mu$. Draw the 2 Feynman diagrams of the productions and decay.

3. In this case, the lepton energy is extremely well measured. What makes the measurement of the mass peak impossible ?

4. We consider only the u-$\bar{d}$ production and we note θ^* the angle between the positron and the beam axis in the center-of-mass (CM) frame. What is the distribution in this frame of differential cross section $d\sigma/d\cos\theta^*$ (see the course or in the exercise sheet 7 for a detailed demonstration).

5. In the center of mass, write ${p_T^e}^2$ as a function of the $\cos^2\theta^*$ using the fact that $m_e,\ m_\nu \ll m_W$.

6. Write $d\sigma/dp_T^e$ as a function of p_T^e, and $d\sigma/d\cos\theta^*$.

7. What is the peculiarity of this distribution that allows to make a measurement of the m_W?

2 W-boson branching ratios

In this exercise we define $\Gamma_\ell \equiv \Gamma(W^- \to e^-\bar{\nu}_e)$ and

1. As a function of Γ_ℓ, give the values of $\Gamma(W^- \to \mu^-\bar{\nu}_\mu)$ and $\Gamma(W^- \to \tau^-\bar{\nu}_\tau)$.

2. As a function of Γ_ℓ, give the values of $\Gamma(W^- \to \bar{u}d')$, $\Gamma(W^- \to \bar{c}s')$ and $\Gamma(W^- \to \bar{t}b')$.

3. Conclude on the value of $\mathcal{B}((W^- \to e^-\bar{\nu}_e)$ and compare to the value found in the PDG.