The $e^+e^- \to \mu^+\mu^-$ Cross Section in the Standard Model

Alex Pearce

March 31, 2012

Abstract

The Standard Model's (SM) prediction of particles beyond those initially considered by quantum electrodynamics (QED) has yielded excellent results. The Super Proton Synchrotron (SPS) at CERN recently detected both the W bosons and the Z boson via the $p\bar{p}$ mechanism (Rubbia, van der Meer et al.). We performed a numerical integration of the differential cross section of the $e^+e^- \to \mu^+\mu^-$ scattering process, which may produce Z bosons, in the hope that the proposed Large Electron-Positron collider (LEP) will verify this channel of Z production. A distinct Z resonance around the Z mass of 91.8GeV was found with a cross section $\sigma = 9.4\text{nb}^{-1}$.

1 Introduction

The proposition of three mediators of the weak nuclear force, the W^+, W^- and Z bosons, has been all but proven by the current team at CERN operating the SPS. The suggestion of Z production via electron-positron pairs is now becoming of interest to experimentalists. The process is manifested by an electron-position pair (e^-e^+) annihilating, forming either a virtual photon or Z boson, and then a muon-antimuon pair ($\mu^-\mu^+$) being produced.

This interaction is described by the Feynman diagram in figure 1a. The scattering is also described by a t-channel diagram (in figure 1b), however we proceed by analysing only the s-channel as it is only this channel via which we may measure resonances and new unstable particles. Note that a u-channel diagram also exists, but as it is simply a swapping of the outgoing particles' momenta in the t-channel, we ignore this also.

The use of Feynman diagrams is that we may apply the Feynman rules to them to produce a matrix element $\mathcal{M}$. This in fact corresponds to a differential cross section $\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}$ which may be integrated to find the total cross section σ, which is measurable by a detector.

The methods of integration used are explored in the next section, along with a study of the differential cross sections in order to judge the effectiveness of numerical integration upon them. The results are presented and analysed in section 3, then a discussion of the kinematic variables follows in section 4. Finally, TODO is considered in section 5

2 Integration of the Differential $\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}$

History.

3 Results and Analysis

TEX

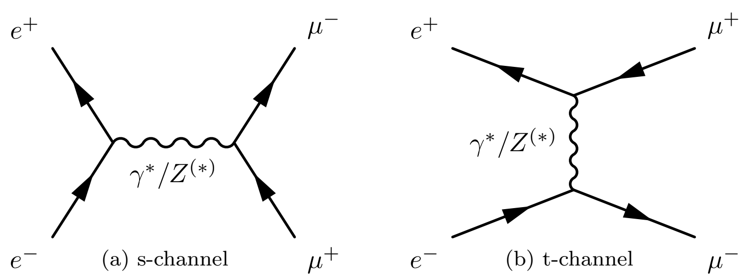
4 Kinematic Variables

Discussion of $\cos\theta$ and $p_T = |\vec{p}_f| \sin\theta$.

5 Extension

TODO Extension of the problem.

6 Figures



(a) s-channel (b) t-channel

Figure 1: $e^- e^+ \to \mu^- \mu^+$ scattering via two different channels.

References