Master Advanced Lab Course
Universität Göttingen – Fakultät für Physik

Report on the experiment KT.WZE

W/Z experiment at the Tevatron

Name:	Eric Bertok
Email:	eric.bertok@stud.uni-goettingen.de
Conducted on	24th January 2018
Assistant:	Dr. J. Veatch
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1 Introduction

In goal of this experiment is the determination the of the branching ratio of the W boson BR($W \to \mu\nu$). First, W and Z bosons are reconstructed using data provided by the Tevatron collider at Fermilab. By comparing with Monte Carlo simulations, selection parameters are obtained, which allow for clean cuts for filtering out background events (jets and cosmic source). The mass and the transverse mass is then determined for the Z and W boson respectively. Finally the branching ratio is calculated from the number of selected events, the trigger efficiencies, as well as the reconstruction efficiencies.

2 Theory

2.1 Electroweak interaction

The GWS theory (Glashow, Weinberg, Salam) is the unified description of both the electromagnetic force mediated by the photon and the weak interaction mediated by the massive W^+, W^- and the neutral neutral Z boson. It was confirmed experimentally in the 1970s [1]. The gauge bosons are introduced by means of a local SU(2)$_L$ gauge symmetry in a weak isospin space. The weak isospin doublets are formed by fermions differing by one unit of charge [2, p.;416]. By also replacing the U(1) symmetry by a new U(1)$_Y$ symmetry with the "hypercharge" Y, the neutral Z boson can be identified by a linear combination of the neutral $W^{(3)}$ boson and the B boson coupling to the hypercharge. More details can be found in [2, p. 418ff]. Being a charged boson, the W bosons couple to fermions differing by one unit of charge. Furthermore it maximally violates parity as it only couples to left-handed particles and right-handed antiparticles. The vertex factor is given by [2, p.;409]

$$-i\frac{g_W}{\sqrt{2}}\frac{1}{2}\gamma^\mu(1-\gamma^5), \tag{2.1}$$

where g_W is the weak coupling constant and γ^μ are the gamma matrices. The Z boson however, couples to any pair of identical fermions, albeit coupling more strongly to left handed ones. This becomes apparent in the form of the vertex factor: [2, p. 432]

$$-i\frac{1}{2}g_Z\gamma^\mu(c_V - c_A\gamma^5), \tag{2.2}$$

with the vector and axial vector couplings c_V and c_A.

2.2 Matrix elements and Decay rates

The matrix elements for the electroweak interaction can be calculated with the appropriate Feynman rules. After averaging over the three possible polarizations, the spin-averaged matrix element squares is obtained for both the W and the Z boson decaying to a lepton and its neutrino or a lepton- anti-lepton pair, respectively [2, p.;242,411]:

$$\langle|\mathcal{M}_W^2|\rangle = \frac{1}{3}g_W^2 m_W^2 \tag{2.3}$$

$$\langle|\mathcal{M}_Z^2|\rangle = \frac{1}{3}(c_V^2 + c_A^2)g_Z^2 m_Z^2. \tag{2.4}$$

These can be inserted into the decay rate formula: [2, p. 411]

$$\Gamma = \frac{p^*}{32\pi^2 m^2}\int \langle|\mathcal{M}^2|\rangle \,\mathrm{d}\Omega = \frac{p^*}{8\pi m^2}\langle|\mathcal{M}^2|\rangle, \tag{2.5}$$

where m is the mass of the boson and $p*$ is the momentum of the lepton in the center of mass frame. For $e^+ - e^-$ colliders such as LEP, one can argue that $p* = m_Z/2$, as the decay happens in the centre of mass frame. Therefore the decay rate is

$$\Gamma(W^- \to e^-\bar{\nu}_e) = \frac{g_W^2 m_W}{48\pi}. \tag{2.6}$$

3 Execution

4 Analysis

5 Discussion

References

[1] https://de.wikipedia.org/wiki/Elektroschwache_Wechselwirkung. – Zugriff:2018-01-31

[2] *Modern Particle Physics*. Cambridge University Press, 2013