Four Memos for the Next Millennium: A Brief Future of Particle Physics

Fermilab Academic Lecture Series — Chris Quigg

Exercise for Lecture 1
March 17, 1995

1. LEP measurements on the Z^0 were summarized at the Glasgow International Conference on High Energy Physics (July 1994) by Dorothée Schaile (CERN-PPE-94-162, compressed PostScript file available on WWW at
   `http://darssrv1.cern.ch/archive/electronic/cern/9411/ppe94-162.ps.Z`)
   as follows:

M_Z	91.1888 ± 0.0044 GeV/c^2
Γ_Z	2.4974 ± 0.0038 GeV
$\Gamma(Z \to \text{hadrons})$	1745.9 ± 4.0 MeV
$\sigma_{\text{had}}(\text{pole})$	41.49 ± 0.12 nb
$\Gamma(Z \to e^+e^-)$	83.85 ± 0.21 MeV
$\Gamma(Z \to \mu^+\mu^-)$	83.95 ± 0.30 MeV
$\Gamma(Z \to \tau^+\tau^-)$	84.26 ± 0.34 MeV
$\Gamma_{\text{leptonic}} = \Gamma(Z \to \ell^+\ell^-)$	83.96 ± 0.18 MeV
$\Gamma_{\text{invisible}}$	499.8 ± 3.5 MeV
a_e	-0.501 ± 0.001
v_e	-0.038 ± 0.002

   Let us confront these results with the lowest-order predictions of the spontaneously broken $SU(2)_L \otimes U(1)_Y$ (Weinberg–Salam) electroweak theory.

   (a) Use the value of the Z^0 mass to determine $x_W \equiv \sin^2\theta_W$.

   (b) Using your value of x_W, predict the $W^\pm$ mass and compare it with the latest measurement by the CDF Collaboration (F. Abe, *et al.*, Fermilab–PUB–95/035–E, available on WWW at `http://www-cdf.fnal.gov/physics/pub95/cdf2928_wmass_prl_subm.ps`): $M_W = 80.410 \pm 0.180$ GeV/c^2.

   (c) Use the measured value of the Z^0 mass to predict the partial width $\Gamma(Z \to \nu\bar{\nu})$. By comparing with $\Gamma_{\text{invisible}}$ measured at LEP, determine the number of light neutrino species.

   (d) Use your value of the weak mixing parameter x_W to predict $\Gamma_{\text{leptonic}} = \Gamma(Z \to \ell^+\ell^-)$, $\Gamma(Z \to \text{hadrons})$, and the electron's axial-vector and vector couplings, a_e and v_e. Neglect the masses of all fermions but the top quark.

   [Reference: C. Quigg, *Gauge Theories of the Strong, Weak, and Electromagnetic Interactions,* §7.1 and 7.2.]

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The exercises to accompany these lectures will be available on World Wide Web. Point your web client to `http://chrisq.fnal.gov/Memos/Exercises.html`.