Lab report
E213 Analysis of Z^0 Decay

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This is abstract.

1 Introduction

This is introduction.

2 Theory

The partial decay width of Z^0 decay into fermion f is

$$\Gamma_f = \frac{\sqrt{2}N_c^f}{12\pi} G_F M_Z^3 \left((g_V^f)^2 + (g_A^f)^2 \right) \tag{1}$$

with

$$\begin{aligned} g_V^f &= I_3^f - 2Q_f \sin^2\theta_W \\ g_A^f &= I_3^f \end{aligned}$$

One needs to be aware that Γ_f contains contribution from both chiralities, and I_3 here refers to only the weak isospin of left-handed fermions (by definition right handed fermions have no weak isospin).

Partial cross section of $Z^0 \to f\bar{f}$ is given by [1]

$$\sigma_f(s) = \frac{12\pi}{M_Z^2} \frac{s\Gamma_e\Gamma_f}{(s - M_Z^2)^2 + (s^2\Gamma_Z^2/M_Z^2)} \tag{2}$$

In $ee \to ee$ scattering, two relevant channels have different angular dependences. For s-channel,

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}_s \sim (1 + \cos^2\Theta) \tag{3}$$

For t-channel,

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}_t \sim (1 - \cos^2\Theta)^{-2} \tag{4}$$

3 Pre-lab tasks

Using equation (1), one finds

$$\Gamma_e = \Gamma_\mu = \Gamma_\tau = 83.40\,\mathrm{MeV} \tag{5}$$

The decay widths to leptons of three generations are the same because of lepton universality and neglecting the masses. With the same equation, decay width to quarks in total is

$$\begin{aligned}\Gamma_u = \Gamma_c \quad\quad &= 285.34\,\mathrm{MeV}\\ \Gamma_d = \Gamma_s = \Gamma_b &= 367.79\,\mathrm{MeV}\end{aligned}$$

It is significantly larger, since there are more quarks in SM and quarks carry more degrees of freedom (color) than leptons. Decays to neutrinos are invisible for detector in LEP, but still they have the width of

$$\Gamma_\nu = 165.84\,\mathrm{MeV} \tag{6}$$

Hadronic part

$$\Gamma_\mathrm{h} = \sum_{\forall q \neq t} \Gamma_q = 1674.06\,\mathrm{MeV} \tag{7}$$

Charged decay

$$\Gamma_\mathrm{charged} = 3\Gamma_e = 250.17\,\mathrm{MeV} \tag{8}$$

Invisible decay

$$\Gamma_\mathrm{inv} = 3\Gamma_\nu = 497.52\,\mathrm{MeV} \tag{9}$$

In total (except unknown decays)

$$\Gamma_\mathrm{total} = 3\Gamma_e + \Gamma_h + 3\Gamma_\nu = 2421.75\,\mathrm{MeV} \tag{10}$$

decay type	partial width/MeV	partial cross section/$10^{-5}\mathrm{MeV}^{-2}$
hadronic	1674.06	10.79
charged	250.17	1.61
invisible	497.52	3.21
total	2421.75	15.61

Table 1: Decays widths and partial cross sections

Assume that there is another generation of light fermions, the total width of Z^0 would be

$$\Gamma'_\mathrm{total} = \Gamma_\mathrm{total} + \Gamma_e + \Gamma_\nu + \Gamma_u + \Gamma_d = 3324.11\,\mathrm{MeV} \tag{11}$$

It would be a change of 37% percent!

The differential cross section $\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}$ has different angular dependencies for s- and t-channels, see equations (3) and (4). Simply plotting without the proportional constant in front shows where s- or t-channels dominates the process, see figure. 1. At small angles, t-channel dominates, whereas at large angles, s-channel dominates.

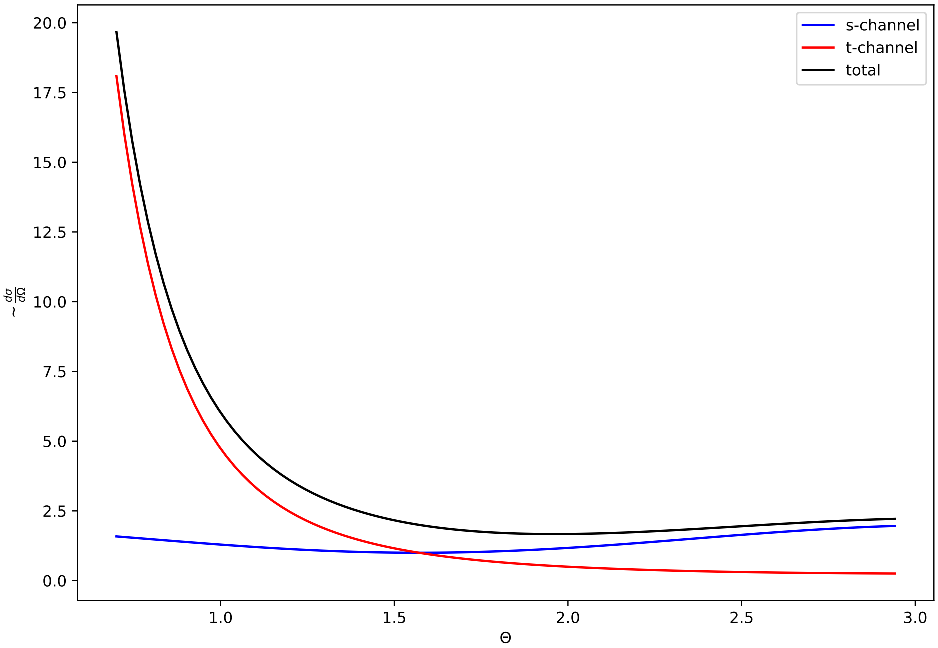

Figure 1: Angular dependencies of two channels.

4 Procedure

5 Analysis

6 Conclusion and outlook

References

[1] Unknown. *E213 Analysis of Z0 Decay*.