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Cross Section:

- Detector/acc. indpnt
- Encodes reactivity / interactivity
- fb : Femto barns i.e. $10^{-43} m^2$

Resonance Width:

- The WAHM for a $d\sigma$ vs $\sqrt{s}$ plot
- $\Gamma = \frac{\hbar}{\tau}$ $\tau \rightarrow$ Lifetime

Radiation length

- X_0
- The distance over which a high energy electron loses all but 1/e of it's energy in a material through Bremstralung
- Or 7/9 of the mean free path for pair production by a photon

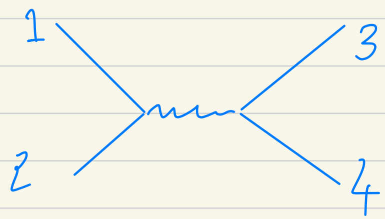
s-channel

↳ $s = (P_1 + P_2)^2 = (P_1' + P_2')^2$

↳ Measure of E_{CM} i.e.

↳ "The only way that resonances and new particles may be discovered provided their lifetimes are long enough that they are directly detectable"

↳ Particles 1 and 2 join to produce an intermediate particle which then splits into particles 3 and 4



↳ $\mathcal{M} \sim \frac{1}{s}$

↳ Invariant amplitude

↳ $s \sim 1 + \cos^2(\Theta)$

t-channel

↳ $t = (p_1 - p_1')^2 = (P_2' - P_2)^2$

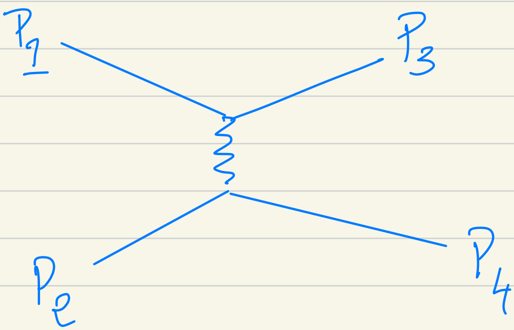
↳ Measure of 4-momentum transfer "square"

↳ $\mathcal{M} \sim \frac{1}{t}$

↳ $t \sim \frac{1}{(1-\cos\Theta)^2}$

↳ P_1 emits an intermediate and becomes P_3

↳ P_2 absorbs the intermediate and emits P_4



Pre

Lab

Questions

Q 5.1

We have the general formula for partial width:

$$\Gamma_f = \frac{\sqrt{2}}{12\pi} N_c^f \cdot G_F \cdot M_Z^3 \left[(g_V^f)^2 + (g_A^f)^2 \right] \quad \text{1.}$$

Where, $N_c^f = \begin{cases} 1, \text{ for Leptons} \\ 3, \text{ for Quarks} \end{cases}$, Colour factor

$G_F = 1.16638 \times 10^{-5}\ \text{GeV}^{-2}$, Fermi's constant

$M_Z = 91.182$ GeV, Mass of Z^0

$g_V^f = I_3^f - 2Q_f \sin^2\theta_W$, vector coupling

$g_A^f = I_3^f$, axial vector coupling

Q_f = Electric charge in units of the elementary charge

I_3^f = Third component of the weak isospin

$\sin^2\theta_W = 0.2312$

↳ Weinberg Mixing angle

a) $Z^0 \to e^+e^-$

$$\boxed{\Gamma_e^{obv} = 83.8\,\text{MeV}, \quad \Gamma_e^{Calc} = 83.4\,\text{MeV}}$$ 2

b) $Z^0 \to \mu^+\mu^-$

$$\boxed{\Gamma_\mu^{obv} = 83.8\,\text{MeV}, \quad \Gamma_\mu^{Calc} = 83.4\,\text{MeV}}$$ 3

c) $Z^0 \to \tau^+\tau^-$

$$\boxed{\Gamma_\tau^{Obv} = 83.8\,\text{MeV}, \quad \Gamma_\tau^{Calc} = 83.4\,\text{MeV}}$$ 4

d) $Z^0 \to q^+q^-$

$$\boxed{\begin{array}{l} \Gamma_u^{Obv} = 299\,\text{MeV}, \quad \Gamma_u^{Calc} = 285.4\,\text{MeV} \\[2em] \Gamma_d^{obv} = 378\,\text{MeV}, \quad \Gamma_d^{Calc} = 367.8\,\text{MeV} \end{array}}$$ 5

Q 5.2

We shall do (a) finally. We have the following formula for partial cross section at max. res:

$$\boxed{\sigma_f^{Peak} = \frac{12\pi \Gamma_e \Gamma_f}{M_Z^2 \Gamma_Z^2}} \quad \text{—— } (6)$$

b) $\Gamma_{Hadronic} = \Gamma_u + \Gamma_c + \Gamma_d + \Gamma_s + \Gamma_b$

w.k.t,

$$\Gamma_u = \Gamma_c$$

$$\Gamma_d = \Gamma_s = \Gamma_b$$

$$\Rightarrow \quad \Gamma_{Hadronic} = 2\Gamma_u + 3\Gamma_d$$

From (5)

$$\boxed{\Gamma_H = 1674.17 \text{ MeV}} \quad \text{—— } (7)$$

From (7) and (6)

$$\boxed{\sigma_H^{Peak} = 10.793 \times 10^{-11} \text{ MeV}^{-2}} \quad \text{—— } (8)$$

c) $\Gamma_{\text{Charged Lept.}} = \Gamma_e + \Gamma_\mu + \Gamma_\tau$

w.k.t, $\Gamma_e = \Gamma_\mu = \Gamma_\tau$

$\Rightarrow \quad \Gamma_{\text{Charged Lept.}} = 3 \cdot \Gamma_e$

$$\boxed{\Gamma_{cl} = 250.185 \text{ MeV}} \quad 9.$$

From 6. and 9.,

$$\boxed{\sigma_{cl}^{\text{Peak}} = 1.613 \times 10^{-11} \text{ MeV}^{-2}} \quad 10.$$

d) $\Gamma_{\text{Neutral Lept.}} = \Gamma_{\nu_e} + \Gamma_{\nu_\mu} + \Gamma_{\nu_\tau}$

w.k.t, $\Gamma_{\nu_e} = \Gamma_{\nu_\mu} = \Gamma_{\nu_\tau}$

$$\Rightarrow \quad \boxed{\Gamma_{\text{Charged Lept.}} = 3 \cdot \Gamma_{\nu_e} = 497.556 \text{ MeV}} \quad 11.$$

From 6. and 11.,

$$\boxed{\sigma_{nl}^{\text{Peak}} = 3.2076 \times 10^{-11} \text{ MeV}^{-2}} \quad 12.$$

a) $\Gamma_Z = \Gamma_{Hadronic} + \Gamma_{Neutral.Lept} + \Gamma_{Charged.Lept}$

From 7, 9 and 11 we have

$$\boxed{\Gamma_Z = 2421.91 \text{ MeV}} \quad (13)$$

e) Answered in each part separately.

$$* \quad \boxed{\Gamma_{\nu_e} = 165.85 \text{ MeV}} \quad (14)$$

Q 5.3

$$\Gamma'_{Total} = \Gamma_{Total} + \Gamma_e + \Gamma_\gamma + \Gamma_u + \Gamma_d$$

From 7., 9., 11., 13. and 14. we have:

$$\boxed{\Gamma'_{Total} = 3324.24 \text{ MeV}} \quad 15.$$

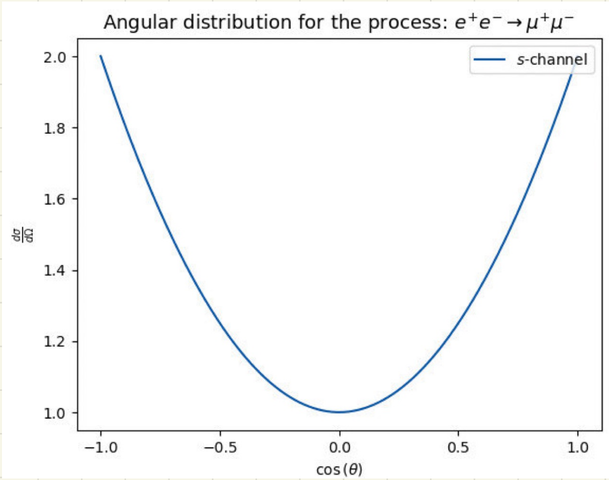
The percentage increase in the width of the resonance curve can be calculated as:

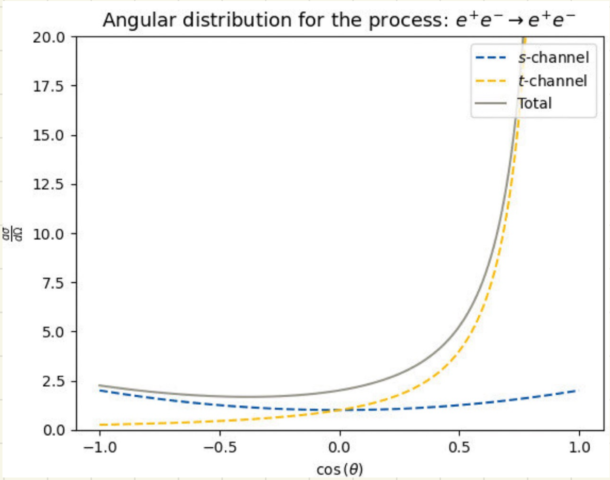
$$\Delta\Gamma = \frac{\Gamma'_{Total} - \Gamma_{Total}}{\Gamma_{Total}} \times 100$$

$$\Delta\Gamma = \frac{902.42}{2421.91} \times 100$$

$$\boxed{\Delta\Gamma = 37.26\%} \quad 16$$

Q 5.4


Angular distribution for the process: $e^+e^- \to \mu^+\mu^-$
s-channel
$\frac{d\sigma}{d\Omega}$
2.0
1.8
1.6
1.4
1.2
1.0
−1.0
−0.5
0.0
0.5
1.0
cos(θ)


Angular distribution for the process: $e^+e^- \to e^+e^-$
s-channel
t-channel
Total
$\frac{d\sigma}{d\Omega}$
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−1.0
−0.5
0.0
0.5
1.0
cos(θ)

Q 5.5

$E_{cm}/\sin^2\theta_W$	0.21	0.23	0.25
89.225	−0.0937	−0.1639	−0.1948
91.225	0.0762	0.0228	0.0042
93.225	0.2317	0.1965	0.1906

References: