Midterm #2

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33-444

1) Particles in SM:

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fermions: $\begin{pmatrix} \nu_e \\ e \end{pmatrix} \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}$ ← all spin 1/2 + antiparticles

$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$ ← 3 colors of each, all spin 1/2

bosons: $Z, W^{+/-}$, γ, 8 gluons, ← all spin-1

H ← spin 0

2) The coupling constant w/ a factor α is different for each force. Also, weak force bosons are massive.

+1

Strong force?

3) $Br(\overset{WZ}{\cancel{WZ}} \to \ell\nu\nu\nu)$

$= \cancel{\{e,\bar{\nu}_e, \nu,\bar{\nu}\} + \{\mu,\bar{\nu}_\mu,\nu,\bar{\nu}\}}$

$\cancel{\{e,\nu,\nu,\bar{\nu}\}, \mu\bar{\nu},\nu,\bar{\nu}\} \{\tau,\bar{\nu}_\tau,\nu,\bar{\nu}\}}$

$= \cancel{Br(W \to \ell\nu)}$ or $\cancel{Br(W \to \nu\nu)}$

$\cancel{\text{and } Br(Z \to \ell\nu\nu)}$ $\cancel{\text{and } Br(Z \to \ell\ell)}$

$= \cancel{\frac{1}{(3 + 2 \cdot 3)}}$ ← not fun

← sorry, see next page

3) $Br\left(WZ \to \left(e/\mu + \nu\nu\nu\right)\right)$

$$= Br(W \to e/\mu + \nu) \cdot Br(Z \to \nu\nu)$$

$$\left(\frac{\{e, \bar{\nu}_e\} + \{\mu, \nu_\mu\}}{3 \text{ leptons} + 3 \cdot 2 \text{ quark ways}}\right) \cdot \left(\frac{3 \text{ neutrino pairs}}{6 \text{ lepton ways} + 3 \text{ colors} \cdot 5 \text{ quark ways}}\right)$$

$$= \left(\frac{2}{9} \cdot \frac{3}{21}\right)$$

$$\boxed{= \frac{2}{3} \cdot \frac{1}{21} = \frac{2}{63}}$$

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4) Higgs Decay:

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WW (Br ~ 20%) boson decays to e or μ^-

ZZ (Br ~ 3%)

$\gamma\gamma$ (Br ~ .2%)

$$Br(WW \to l\nu l'\nu') = \left(\frac{\overset{\text{either } e^- \text{ or } \mu^-}{}}{(3\, l\nu) + (3\,\text{colors} \cdot 2\,\text{generations of quarks})} \right)^2 = \left(\frac{2}{9}\right)^2 = \boxed{\frac{4}{81} = Br(WW \to l\nu l'\nu')}$$

no top quark decays

$$Br(ZZ \to ll\,l'l') = \left(\frac{\text{either } e^-e^+ \text{ or } \mu^-\mu^+}{6 \text{ leptons} + 3 \cdot 5 \text{ possible quarks}} \right)^2 = \left(\frac{2}{21}\right)^2$$

$$\Rightarrow \boxed{Br(ZZ \to ll\,l'l') = \left(\frac{2}{21}\right)^2} \sim \frac{1}{100}$$

w/ these factors

$Br(H \to WW \to l\nu l\nu)$ becomes $\frac{1}{5} \cdot \frac{4}{81} \sim \frac{1}{100}$

$Br(H \to ZZ \to ll\,l'l')$ becomes $\sim \frac{1}{100} \cdot \frac{3}{100} = \frac{3}{10000}$

$Br(H \to \gamma\gamma) = .2\% = \frac{1}{1000}$

$\Rightarrow$ rank

(1) WW ← most events

(2) $\gamma\gamma$

(3) ZZ ← least

5) ~~accelerators~~

(a) the ~~energy~~ available power (to create a magnetic field) limits the energy of circular proton accelerators. Also, there will be more synchrotron radiation.

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(b) limits to the circular electron accelerators are also synchrotron radiation, but this will become more apparent since ~~they need more energy to be accelerated to same energy~~ (~~since they~~ they will go faster than the protons at some energy (since they have less mass).

6) $e^- e^+$ collisions

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(a) $R(E_{cm}) \equiv \dfrac{\sigma(ee \to jets)}{\sigma(ee \to \mu\mu)}$

E_{cm} measured near $2 \cdot m_c$

$\sigma \sim \frac{1}{E_1 E_2} |M|^2 d\Pi_{lips}$

as you go above $2 \cdot m_c$, you would expect more jets to be made, ~~so~~ we expect

$R(m < 2m_c) \sim$ goes to 0

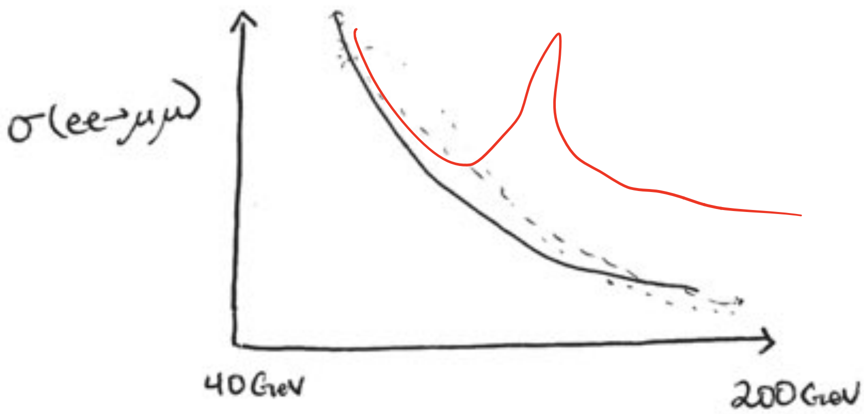
See solutions

$R(m > 2m_c) \sim$ goes to ∞

(over)

6 cont'd)

(b) Cross section of $ee \to \mu\mu$, function of E_{CM}



7) <u>Collider Detectors:</u>

(a) ~~[illegible]~~ μ^-'s behave like heavy e^-'s as they are 2nd generation, but they have a ~~longer lifetime~~ than e^- and will go farther in detector.

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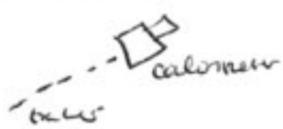
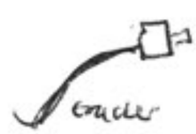
(b) photons have no charge and do not "curve" in tracker look like



e^-'s do appear in tracker



8) Hadronic showers are more difficult since there are more complex reactions going on than just $\gamma \to e^- e^+$ or $e^- \to e^- \gamma$ as seen in EM showers.

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9) $m_x \sim 2\,TeV = 2000\,GeV$

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$x \to ee$ or $x \to \mu\mu$?

Expect to measure mass more precisely w/ $x \to ee$ since the $e^- e^-$s are stopped in the calorimeters. This gives an accurate reading to their energies which can be used to select for the m_x 4-vector.

10) νs are detected by comparing what was measured in the beginning vs at the end. If these energies are not equal, then νs were created.

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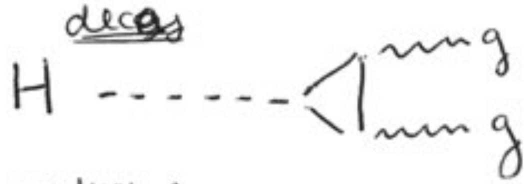
11) decays

(a) 

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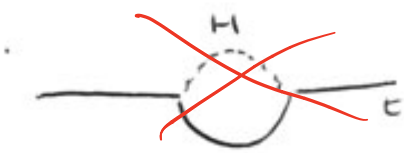
production:



(b) Higgs show up in the "looped" feynman diagrams which appear less often than the W or Z bosons.

12) Higgs decays to pairs of leptons:

$H \rightarrow (\ell \ell)$

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The decay mode of $H \rightarrow ee^{+}$ would be best to study couplings to higgs fields. The ~~e~~ e's can easily be studied (w/ accurate reading of energy) @ the LHC. The coupling could then easily be found.

13) (a) the group symmetry we input (e.g. $SU(2)_L \times U(1)$) dictates the particle content [i.e. what particles satisfy this symmetry]

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(b) electroweak symmetry groups are $SU(2)_L$ [left handed] and $U(1)$

(c) as a result, only left handed ~~protons~~ νs obey the symmetry. In other words, ν_R may as well not exist in the standard model. as they do not interact

14)

(a) spontaneous symmery breaking is when you have ~~a~~ "displaced" minima about the 0 in your field. A minima is randomnly chosen, thus spontaneously beaing symmery in order to give a non-negative mass to the particle.

(b) SSB is responsible for giving mass to particles and is closely related to the Higgs field.

(c) The discoveryof the Higgs gives evidence that SSB is actually occuring.

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