Kevin Yost
Pg 1

1) +4

spin $\frac{1}{2}$ $\begin{pmatrix} e \\ \nu_e \end{pmatrix} \begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix} \begin{pmatrix} \tau \\ \nu_\tau \end{pmatrix} \quad \begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$

spin 1 $\gamma \quad W^{\pm} \quad Z \quad g(\times 8)$

spin 0 h

2) The distance scales for each interaction tricks us. When we observe weak and strong interactions at high energy, they all appear to be similar. Why ?!? +1

3) $Br(ZW \to l\nu\nu\nu) = \underset{\text{combinations}}{2} \left(\frac{1}{\underset{\text{leptons}}{6} + 3(6 \text{ quarks})} \right)$

$\cancel{= 2 \left(\frac{1}{24} \right)}$

$Br(ZW \to l\nu\nu\nu) = \frac{1}{12}$ +2

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4) $Br(WW \to l\nu l\nu) = 2 \times \left(\frac{1}{3+3(2)}\right)^2$ +2

$= 2\left(\frac{1}{9}\right) = \left(\frac{2}{9}\right)$ $e^-\mu^+$ or μ^-e^+

$Br(ZZ \to llll) = 16 \times \left(\frac{1}{3+3(2)}\right)$

$\underset{\text{combinations}}{\overset{4}{}}$ $= 16\left(\frac{1}{9}\right) = \frac{16}{9}$

? ee μμ

$Br(ZZ \to llll) > Br(WW \to l\nu l\nu)$

5) • all charged particles in circular accelerators are limited by the magnitude of the magnetic field, as we can only produce ~20 T → pp +4

• also, charged particles moving in a circle are subject to power loss by synchrotron motion → ee

6) a) $R = \frac{\sigma(ee \to jets)}{\sigma(ee \to \mu\mu)} = \sum_{quarks} Q^2_{quarks}$

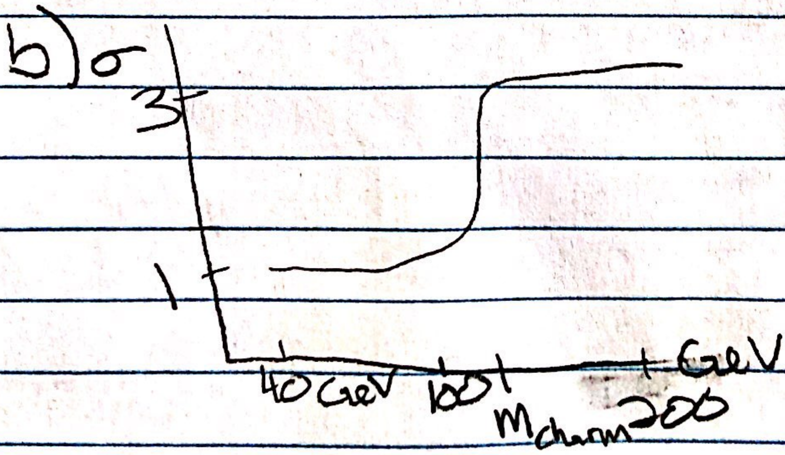
changes like the sum of the charges squared +3

$R(E < 2M_{charm}) = \frac{1}{9} + \frac{1}{9} + \frac{4}{9} = \frac{2}{3}$

$R(E > 2M_{charm}) = \frac{1}{9} + \frac{1}{9} + \frac{4}{9} + \frac{4}{9} = \frac{10}{9}$

× colors

b)



7) a) The signals are both obtained using trackers due to ionizing radiation. The muons are able to pass through the lead in the calorimeters, while the e^-s are measured and stopped by the calorimeters +4

b) electrons and photons are both tracked by trackers. The e^- paths are curved by the B Field, and the γ remain straight. The e^-s and γs are both measured by calorimeters through EM showers

8) Hadronic showers are more difficult. +4
EM showers can be measured simply through radiation loss (also true for π^0 decay). $\pi^{+/-}$ decays are much more complicated and not easily measured

9) More precise mass measurement from $X \to ee$. We can get a more accurate energy reading from ee due to the interaction with calorimeters (both $X \to ee$, $X \to \mu\mu$ couplings are the same) +3

10) νs are not detected, they can be inferred due to momentum gaps in the transverse plane of a collision, but you need to find all other momenta first. +2

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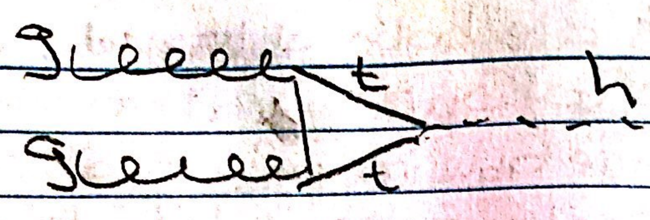
11) a)



decay

+3

b) This is not a first-order diagram. It requires both a strong and a weak interaction to take place, whereas you only need a weak interaction to get W, Z

12) The best way to see this is for the h decays first to WW or ZZ and then to $\ell\ell + (\ell\ell$ or $\nu\nu)$ you could also see it from $h \to \gamma\gamma$ and then $\gamma \to e^+e^-$.
These are much more likely than $h \to b\bar{b}$ +0

13) a) by local gauge symmetries, the particle content can be determined by the number of generators for the group

+4

b) The symmetry groups
$SU(2)_L \times U(1)$

c) The number of particles can be determined by the generators of $SU(2)_L$ (Pauli matrices) and the constants from $U(1)$

What about in SM?

14) a) Spontaneous Symmetry Breaking is forcing the minimum potential in a Lagrangian to be a non-zero ϕ. This comes from the higgs mechanism

b) This is responsible for determining masses for gauge bosons

c) we have determined a relationship between M_W, M_Z and found their values. It has also led to the discovery of the higgs boson. +6