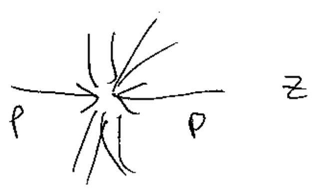
Branching Ratios / Cross Sections

Focus on some particle calculations that we'll use over + over

First cartoon of what/how we measure/detect elem. particles
Motivate certain calculations.

To first order

(We'll come back + make this more precise next week)

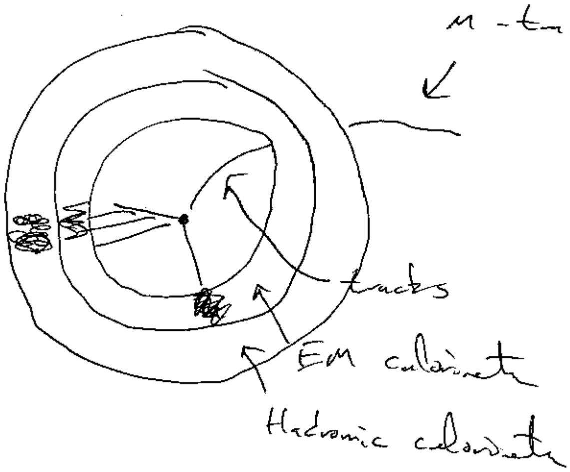


Protons collide along the z-axis
Whole bunch of stuff comes out.

We have detectors "cameras" to take pictures of what comes out.
↪ "Events"

4-basic types of images

$\boxed{\text{Event Display!}}$



Correlations of these 4-basic images tell us what kind of particle was present

Branching Ratios / Cross Section Ratios

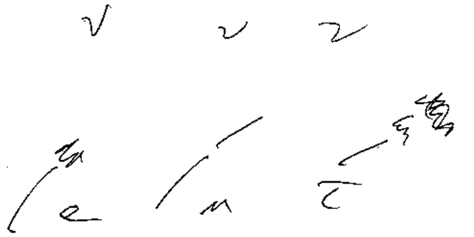
$\begin{pmatrix}\nu\\ e\end{pmatrix}\begin{pmatrix}\nu\\ \mu\end{pmatrix}\begin{pmatrix}\nu\\ \tau\end{pmatrix}$ $\quad\begin{pmatrix}u\\ d\end{pmatrix}\begin{pmatrix}c\\ s\end{pmatrix}\begin{pmatrix}t\\ b\end{pmatrix}\times 3$ colors $\qquad g_{\times 8} \quad \overset{80}{W^{\pm}} \; \overset{90}{Z} \quad \gamma$

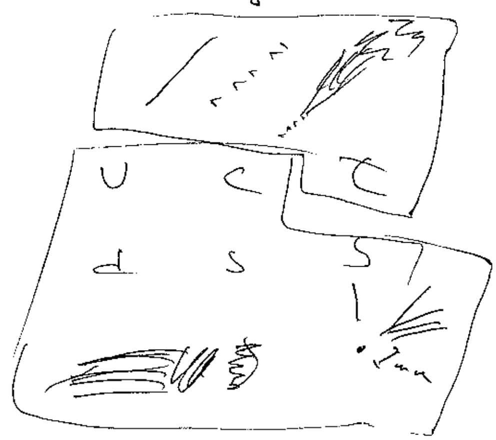
$\begin{pmatrix}\sim 0\\ 10^{-3}\end{pmatrix}\begin{pmatrix}\sim 0\\ 10^{-1}\end{pmatrix}\begin{pmatrix}\sim 0\\ 1.7\end{pmatrix}$ $\quad\begin{pmatrix}0.3\\ 0.3\end{pmatrix}\begin{pmatrix}1.5\\ 0.5\end{pmatrix}\begin{pmatrix}175\\ 5\end{pmatrix}$ masses $\qquad h$ (125 GeV)

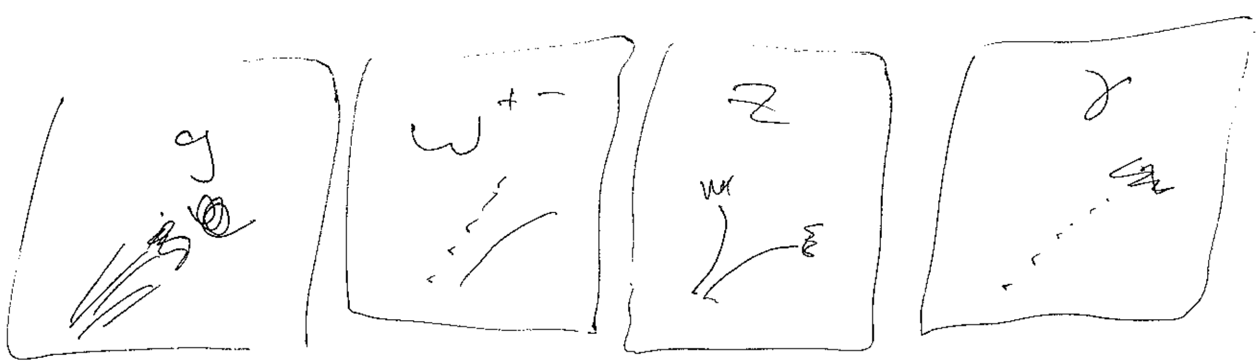
$e \quad \mu$ - easy to tell apart

$\nu_e \, \nu_\mu \, \nu_\tau$ - All look alike distinct from others @ high p_T
(can only tell if 1 or more present)

τ - hard but possible
(some τ's decay to e's + μ's)







Often interested in how often particles decay to

$\ell^{+/-}$ $\{e, \mu, \tau\}$

ν

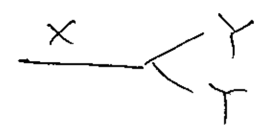
b's

"jets" $\{u\ d\ s\ c\ b\ g\}$

these are what we see in our detectors

-) Probability to decay is given by: $\Gamma = \frac{1}{2E_p} |M|^2 d\Pi_{Lips}$

-) The relative probabilities dictates how often a particle decays a certain way.



$$Br(X \to YY) = \frac{\Gamma(X \to YY)}{\sum_f \Gamma(X \to ff)} = \frac{\cancel{\frac{1}{2E_p}} \cancel{d\Pi_{Lips}} \, |M(X \to YY)|^2}{\cancel{\frac{1}{2E_p}} \cancel{d\Pi_{Lips}} \sum_f |M(X \to ff)|^2}$$

"Branching Ratio" | "Branching Fraction"

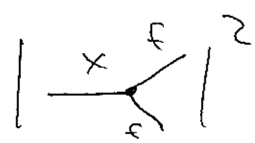
Prob. for particle X to decay to Y

All particles X can decay into

if $m_f, m_Y \ll m_X$ treat m_f & m_Y as massless.

$$Br(X \to YY) = \frac{|M(X \to YY)|^2}{\sum_f |M(X \to ff)|^2}$$

Usually have simple relationships among the M's



eg1 $\boxed{\text{Ex}}$ How often does a Z decay to e^+e^-

$$Br(Z\to ee) = \frac{\Gamma(Z\to ee)}{\sum_f \Gamma(Z\to f\bar f)} = \frac{|M_0|^2}{\sum_f |M_0|^2} = \frac{1}{21}$$

Assume Universal

6 {e μ τ 3ν}
+ 3×5 {6 quarks − top q

$\boxed{2m_t > m_Z}$

Colors

$$Br(Z\to b\bar b) = \frac{3\,|M_0|^2}{\sum_f |M_0|^2} = \frac{3}{21}$$

$\boxed{\text{Ex 2}}$ τ - decays

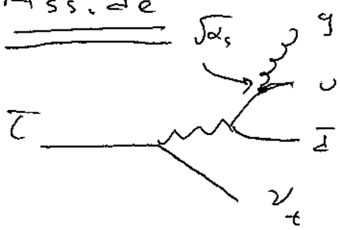
$\begin{pmatrix} e^- \\ \bar\nu_e\end{pmatrix}\begin{pmatrix} \mu^- \\ \bar\nu_\mu\end{pmatrix}\begin{pmatrix} u \\ \bar d\end{pmatrix}\cancel{\begin{pmatrix} c \\ \bar s\end{pmatrix}}\cancel{\begin{pmatrix} t \\ \bar b\end{pmatrix}}$

× 3 too little mass

$$Br(\tau\to e\nu\nu) = \frac{1}{5}$$

$$Br(\tau\to \text{"jets"}) = \frac{3}{5}$$

Aside



Probability for τ → "3 jets"

$$\frac{|M(\tau\to 3\text{"jets"})|^2}{|M(\tau\to 2\text{ jets})|^2} \sim \alpha_s$$

So really

$$Br(\tau\to e\nu\nu) = \frac{|M_0|^2}{5|M_0|^2 + \alpha_s 3|M_0|^2}$$

Size of deviation of $\tau\to e\nu\nu$ from 1/5 measures α_s