

Practically

$$\tau \gtrsim 10^{-18} \text{ s} \left. \vphantom{\tau} \right\} \text{measure lifetime.}$$

$$\tau \lesssim 10^{-18} \text{ s} \left. \vphantom{\tau} \right\} \text{measure Energy Width}$$

$$\Gamma = \frac{\hbar}{\tau} = \frac{\hbar c}{c\tau} \approx \frac{200 \text{ MeV} \cdot \text{fm}}{3 \cdot 10^{23} \frac{\text{fm}}{\text{s}} \cdot \tau \cdot 10^{-18} \text{ s}}$$

$$\approx 70 \cdot 10^{-5} \frac{1}{\tau (10^{-18} \text{ s})} \text{ MeV}$$

$$\Gamma \approx \frac{700}{\tau (10^{-18} \text{ s})} \text{ eV}$$

"Strong Interactions" $c\tau \approx 1 \text{ fm} (!)$

$$\tau \sim \frac{1}{3} \cdot 10^{-23} \text{ s}$$

$$\approx \frac{3 \cdot 10^{-24} \text{ s}}{\text{"1 tick"}}$$

$$\Gamma \approx \frac{700}{3} \cdot 10^6 \text{ eV}$$

$$\Gamma \sim 200 \text{ MeV}$$

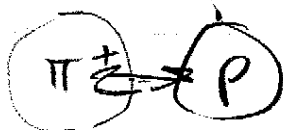
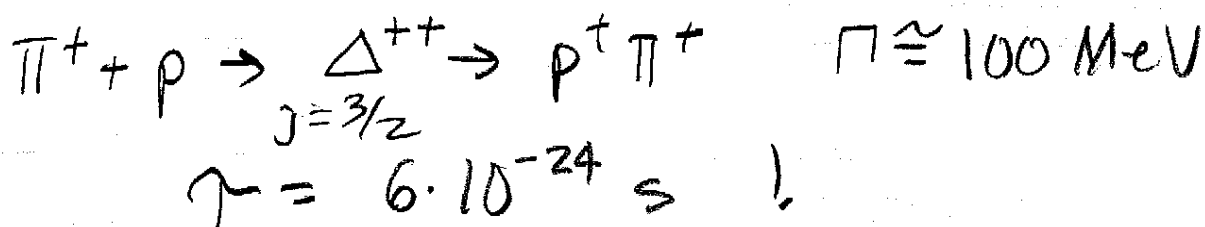
Z^0 ... Width used to "count" neutrinos.

A little about strong interactions "Classic" (Hadron Level)

$\pi^\pm + p \rightarrow ?$ (Fermi post WWII)

See p. 134 of text.

Make short lived resonance

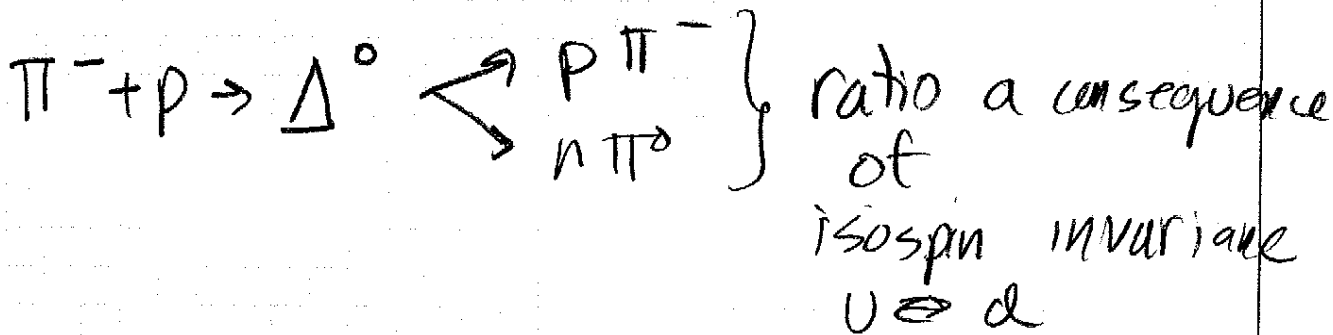


"dance together"

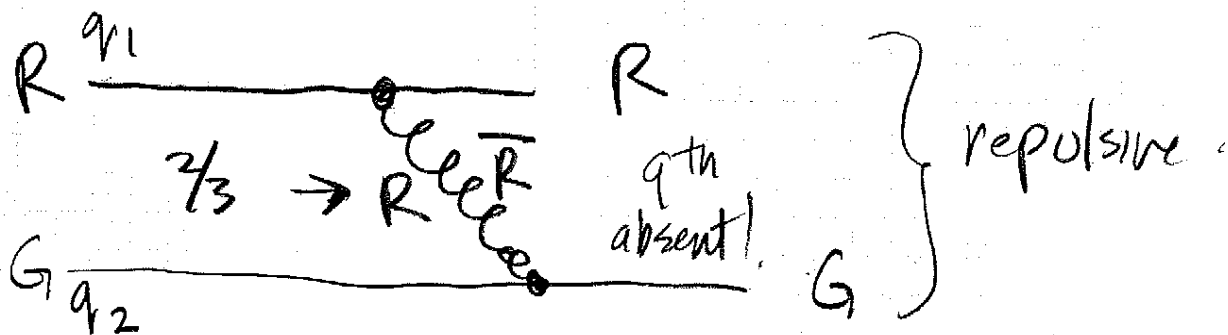
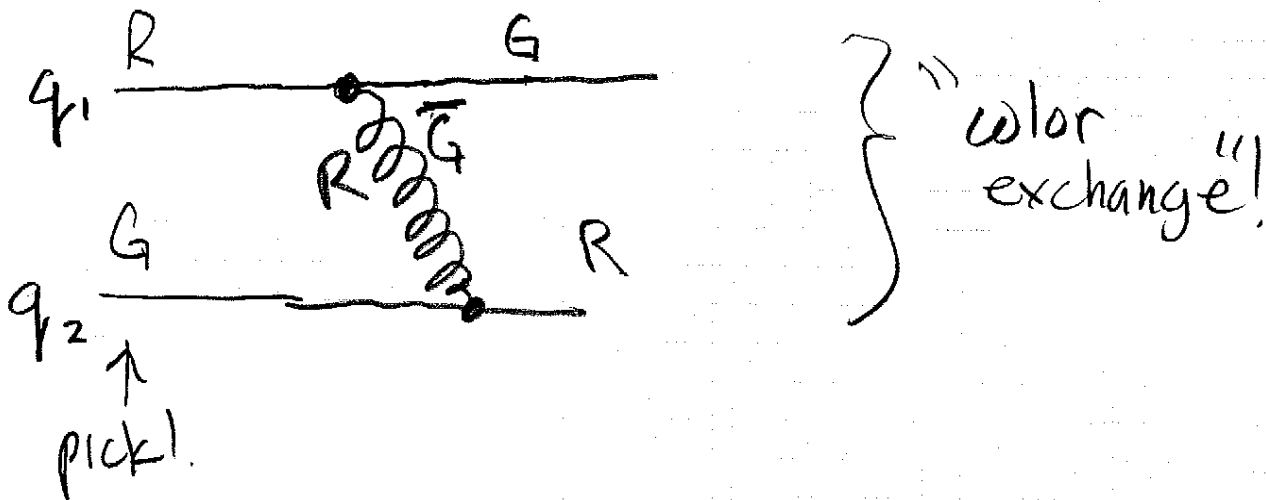
for $\approx 2 \times$ time

to go 1 fm

$\approx 2-4$ hadronic
"radii"



"Quark Level" (simplification)

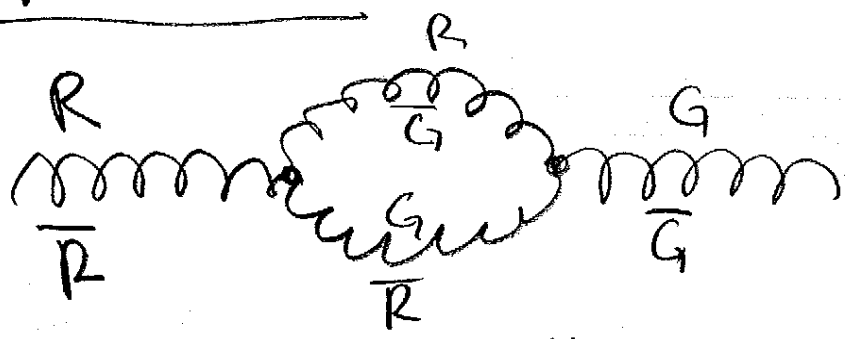


$$H \approx \begin{pmatrix} \frac{2}{3} & 1 \\ 1 & \frac{2}{3} \end{pmatrix} \begin{pmatrix} q_1(R)q_2(G) \\ q_1(G)q_2(R) \end{pmatrix}$$

eigenstates: $\frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ \pm 1 \end{pmatrix}$

eigenvalues: $\frac{5}{3}$ (sum)
 $-\frac{1}{3}$ (difference) $\left. \begin{matrix} \frac{1}{\sqrt{2}} [|q_1(R)q_2(G)\rangle \\ - |q_1(G)q_2(R)\rangle \end{matrix} \right\}$
 quarks attract!

9th Gluon :



More transition "energy"

$$H \equiv \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} A \quad \begin{matrix} R \\ B \\ G \end{matrix}$$

↑
eigenvectors?

$$\frac{1}{\sqrt{3}} \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$$

obvious

ev... 3A

Heavy!

$$\frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix}$$

orthogonal

e.v. 0

$$\frac{1}{\sqrt{6}} \begin{pmatrix} 1 \\ 1 \\ -2 \end{pmatrix}$$

orthogonal to both

e.v. 0 too

ev 0 means 0 mass
like other G