Int. to HEP. Oct. 2, 2007 (1)

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HW: chapter 2 / 1, 3, 7, 8, 10 共5題

Plan: Mainly follow Griffith chapter 2

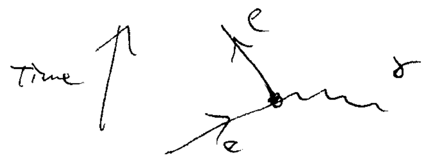
* Four forces:

	Strength	Theory	Mediator	
Strong	10	Q Chromodynamics	Gluon	(1934, Yukawa. 1970s
EM	10^{-2}	Q Electrodynamics	photon	(Maxwell, Dirac; Tomonaga, Feynman, Schwinger 1940
Weak	10^{-13}	$SU(2)_L$	$W^{\pm}$, Z	(Fermi, 1933; Lee, Yang, Feynman, Gell-Mann 1950's; Glashow, Weinberg, Salam 1960s
Gravity	10^{-42}	G.R.	Graviton (↑ Newton, Einstein)	

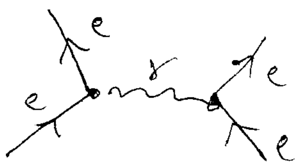
* disturbance of charged particle →
  emission of EM field, carries away energy, momentum ...
  * actually any force is mediated by exchanging the gauge boson.

QED, the oldest, the simplest, most successful of the dynamical theories.

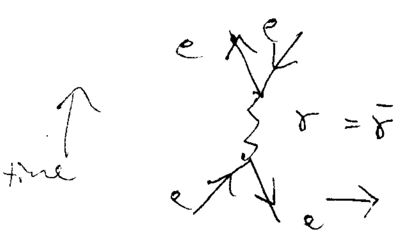
All processes reduce to



↑ could be any charged particle.



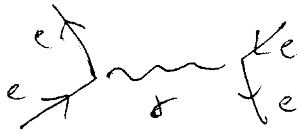
~ Coulomb repulsion of like charges.
= Moller scattering



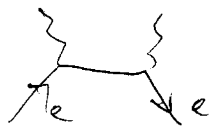
→ running backward in time
= anti particle $= e^+$

~ Bhabha scattering

↳ another diagram give same initial/final states.

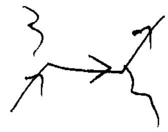


with 2 vertices we can also construct:



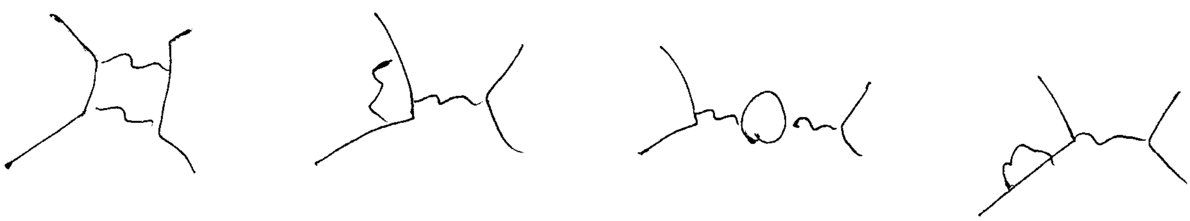
pair annihilation

pair production



Compton scattering

with 4 vertices

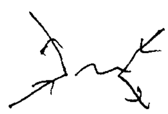


internal lines are not observed. ⇒ virtual particles
external lines : ⇒ real particles
(observables)

Q: what kind of diagrams can you construct from 3 vertices ?

* pure symbolic / do not represent particle trajectories

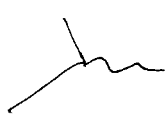
the ~~vert~~ horizontal is not the real spatial position

 is actually attracted to each other

* Each Feynman diagram stands for a NUMBER which can be calculated using Feynman rules.

* Given a physical process, you draw all possible diagrams. and add up all the numbers.
→ infinite #, but $\alpha = \frac{e^2}{4\pi} \simeq \frac{1}{137}$ is very small.

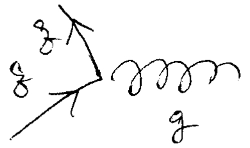
* The Feynman rules enforce E, P conservation at each vertex,

So  is not physical.
or the corresponding number is <u>zero</u>.

* Virtual particle can have any mass. off the mass shell.
$E^2 = m^2 + p^2$

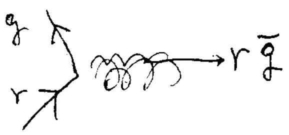
In general, more off-shell, short lived _

* QCD, very similar to QED
* color plays the role of charge in QED.
  the fundamental process is quark - quark - gluon



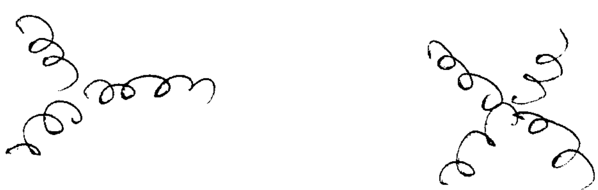
, ⇒

* However, only one kind of charge in QED
  3 kinds of color in QCD
  (r, g, b)



→ bi-color, How many? $3 \times 3 = 9$
⇒ actually only 8 independent combinations

* gluons carry color, ⟺ couple to other gluons.

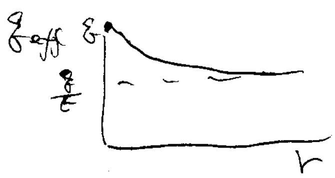


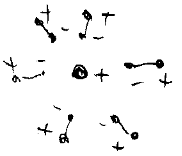
* the nonlinearity makes QCD a lot more complicated
  for instance, glueball

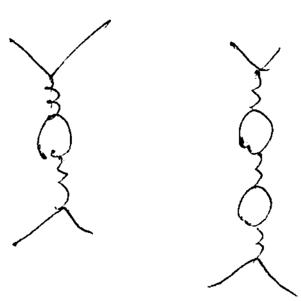
* $\alpha_s \sim 1$ at $\Lambda_{QCD} \simeq 200$ MeV ⇒ nonperturbative.

* Asymptotic freedom. → high energy is perturbative. very good.

In QED

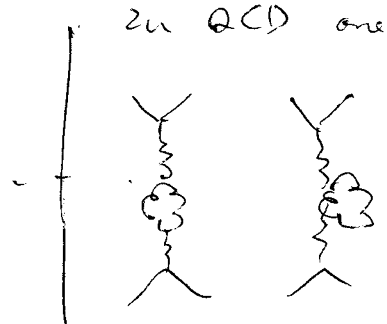






$\beta > 0$

In QCD one also has



$n_f = 6$
$n_c = 3$

$\beta \propto 2n_f - 11n_c < 0$

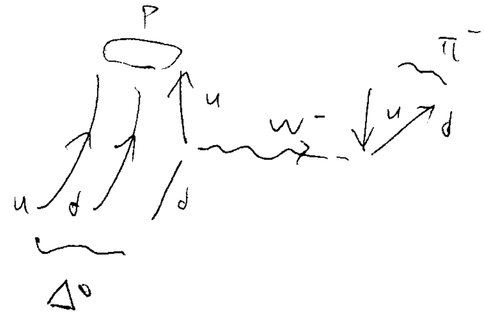
交記束

$\pi^- \to e + \bar{\nu}_e$

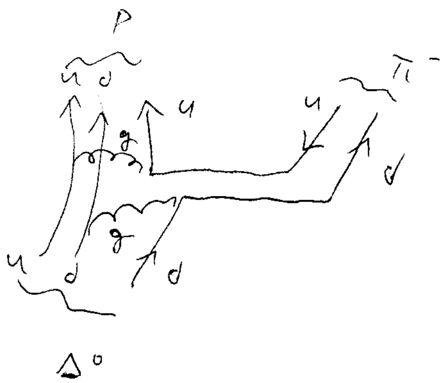
acctually mainly decays into

$\mu + \bar{\nu}_\mu$

like β-decay



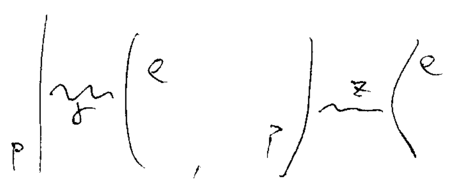
but this also receive large contribution from strong interaction



☆ NC is similar to lepton sector

, can be thought as another kind of photon

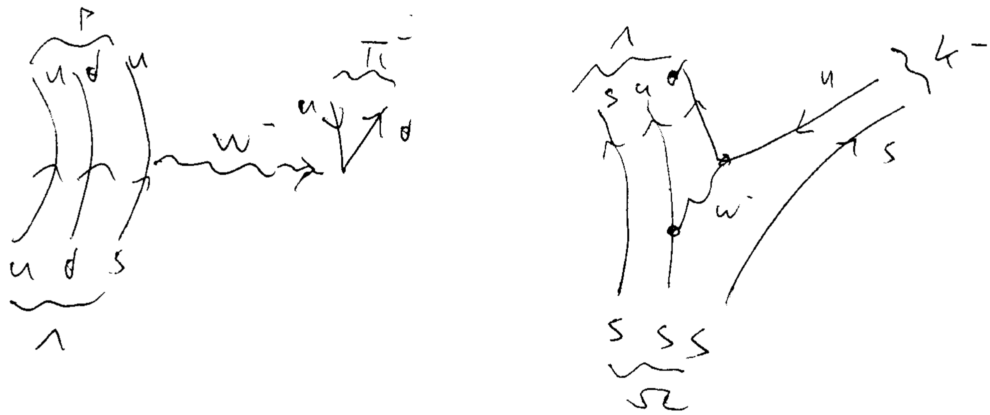
Hydrogen atom



but too small

* not yet ~~this~~ touch the ~~flavor~~ generation changing

e.g. strange quark → up quark



1963 Cabibbo,

1970 Glashow, Illiopoulos, Maiani (GIM)

1973 3 generation ⇒ Kobayashi & Maskawa

$$\begin{pmatrix} u \\ d \end{pmatrix}, \begin{pmatrix} c \\ s \end{pmatrix}, \begin{pmatrix} t \\ b \end{pmatrix} \Rightarrow \begin{pmatrix} u \\ d' \end{pmatrix}, \begin{pmatrix} c \\ s' \end{pmatrix}, \begin{pmatrix} t \\ b' \end{pmatrix}$$

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{matrix} u \\ c \\ t \end{matrix} \overset{\begin{matrix} d & s & b \end{matrix}}{\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$|KM| \sim \begin{pmatrix} 0.9738 & 0.2272 & 4\times10^{-3} \\ 0.2271 & 0.9729 & 4\times10^{-2} \\ 8.1\times10^{-3} & 4\times10^{-2} & 0.9991 \end{pmatrix}$$

PDG booklet p 189.

up-down #

⇒ no charm-strange #, nor top-bottom # conservation

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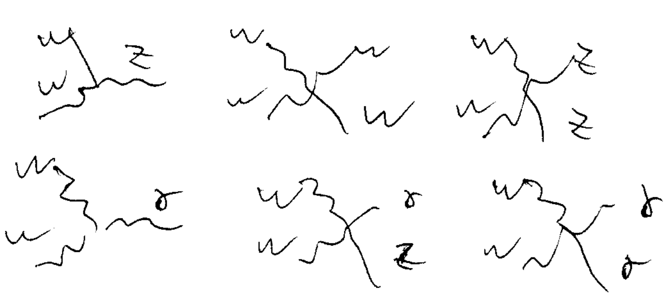
like QCD, W, Z & γ have



☆ Decays & conservation laws.

☆ particles tend to disintegrate -

they like to decay into lighter particles.

(unless prevented from doing so by some conservation law)

νs & photons are stable. $m=0$, nothing lighter than them.

e is stable, (lightest charged particle).

conservation of charge make it stable.

p is stable (lightest baryon, B conserved)

n, p, e, ν_e populate our world.

☆ other exotic ones are produced in collider.

do not last long.

$\tau_{\pi^0} = 8.3\times10^{-17}$ sec, $\tau_\mu \simeq 2.2\times10^{-6}$ sec

$\tau_{\pi^+} \simeq 2.6\times10^{-8}$ sec

☆ Most particles have several different decay modes.

$K^+ \to \mu^+ + \nu_\mu$ ~64% ← branching ratio.

$\pi^+ + \pi^0$ ~21%

$\pi^+ + \pi^+ + \pi^-$ 6%

⋮

☆ Decays are governed by one of the 3 forces.

τ		
~10^{-23} sec	$\Delta^{++} \to p^+ + \pi^-$	strong
~10^{-16} sec	$\pi^0 \to \gamma + \gamma$	E&M → everything associated with γ is E&M.
~10^{-13} sec	$\Sigma^- \to n + e^- + \bar{\nu}_e$	weak.
15 min weak		→ everything associated with νs is weak

☆ If the mass difference is large → fast decay

small → slow $n \to p e \bar{\nu}_e$ ~900 sec

- conservation of E & P.
- angular momentum
- ⋮

} ~~kinetic~~ kinematic conservation laws. apply to all interaction.

⇒ dynamical conservation laws. (symmetry of interaction)

- Conservation of charge.
- color
- baryon #

$B_q = +\frac{1}{3}$, $B_{\bar{q}} = -\frac{1}{3}$

$B_p = +1$, $B_\pi = 0$ . . .

- L_e, L_μ, L_τ.

Weak: same generation, , strong: X, E&M: only charged lepton.

- approximate conservation of flavor,

not in weak int. but since weak force is much weaker than other two. –

historically: strangeness (Gell-Mann)

$\pi^-(d\bar{u}) + p^+(uud) \rightarrow K^+(u\bar{s}) + \Sigma^-(dds)$

$\pi^-(d\bar{u}) + p^+(uud) \not\rightarrow \pi^+(u\bar{d}) + \Sigma^-(dds)$

can't be seen in Lab. buried under strong int.

★ OZI rule!

$\psi = c\bar{c}$, $\tau \sim 10^{-20}$ sec $\sim 1000 \times \tau_{strong}$.

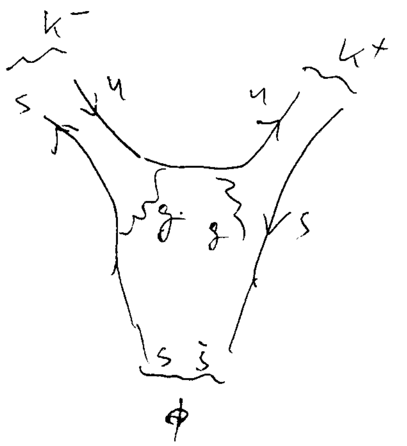
- no charmness, +1, −1 = 0
- still fast, must be strong int. so why?

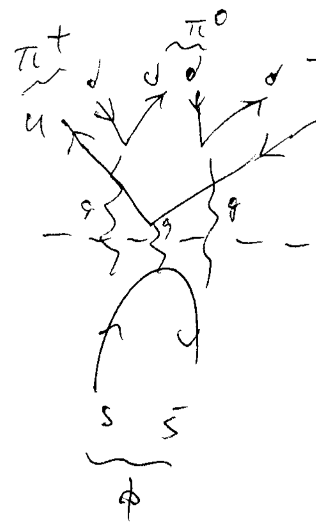
Okubo, Zweig, & Iizuka (OZI rule)

$\phi = s\bar{s} \longrightarrow 2K$ 990 MeV

$\searrow 3\pi$ 415 MeV (2K > 3π)

so why?





⇐ pure gluonic intermediate state

↓

will be suppressed

↓

QCD, asymptotic freedom.

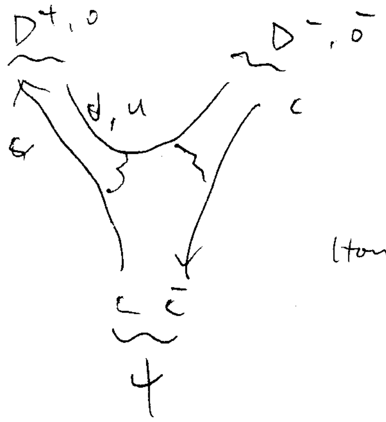
$\alpha_s \downarrow$

soft gluon

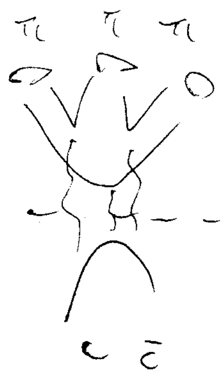
$\alpha_s \uparrow$

OZI allowed

Orz



However, mass $2D > m_\psi$



OZI suppressed → survived

long lived

課堂發問紀錄 Oct 2, 2007

王繼文
張凱維
李政憲
姚欣佑
蕭子絪
李[illegible]泰
潘維平
who ??⇒ 陳[illegible][illegible]
林家正
陳柏榮.