

$$(i\not{\partial} - m)\psi = 0$$

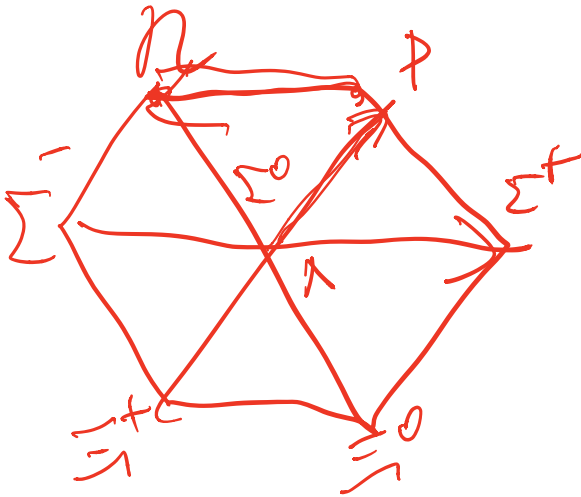
$$(i\not{\partial} + m)\psi = 0$$

$$\Rightarrow (\partial^2 - m^2)\psi = 0$$

$$\Rightarrow p^2 - m^2 = 0$$

$$\Rightarrow E^2 = \vec{p}^2 + m^2$$

$$\Rightarrow E = \pm \sqrt{\vec{p}^2 + m^2}$$

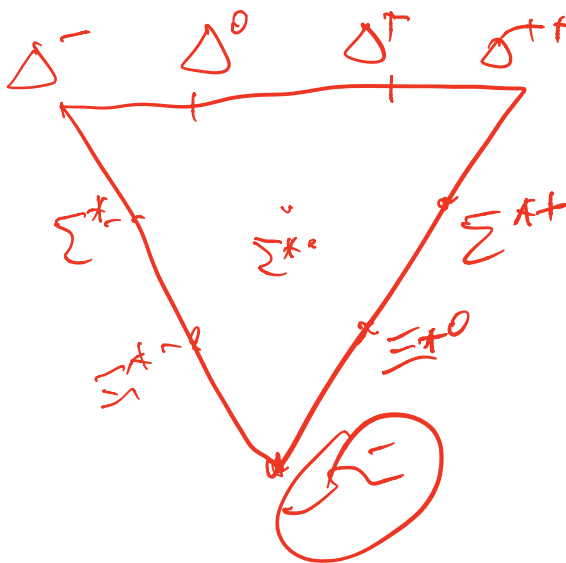


eight-fold.

weight diagram  
SU(3)

SU(2) :  $a^+$   $a^-$

$J^1 \pm iJ^2$



SU(3)    3    ?

↓

Quark

$$3 \otimes \bar{3} = 8 + 1 \quad \text{meson}$$

$$3 \times 3 \times 3 = \underline{10} + \underline{8} + \underline{8} + 1$$

baryon

Question: Quarks. { fermion  
boson?  
charges?

	u	d	s
isospin	$\frac{1}{2}$	$-\frac{1}{2}$	0
strangeness	0	0	-1
charges	$\frac{2}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$

Observe quarks?

quarks  $\rightarrow$  baryon?

$\Delta^{++}$  (uuu, s-wave,  $\uparrow\uparrow\uparrow$ )

X Pauli principle

$$(x_1^2 - x_2^2)(x_2^2 - x_3^2)(x_3^2 - x_1^2)$$

$$[3] : (-1) \quad X$$

$\hookrightarrow$  New internal quantum #  
'color'

QCD

chromo  $\leftarrow$  Chroma

~~QCD~~ Chrome  
 $\varepsilon^{ijk} g^i g^j g^k$

1.2

红	绿	蓝
R	G	B
$\Delta$	$\Delta$	$\Delta$

color-confinement

color-singlet  $\Leftarrow$  Exp.

Theory?

Evidences:

Baryon spectroscopy

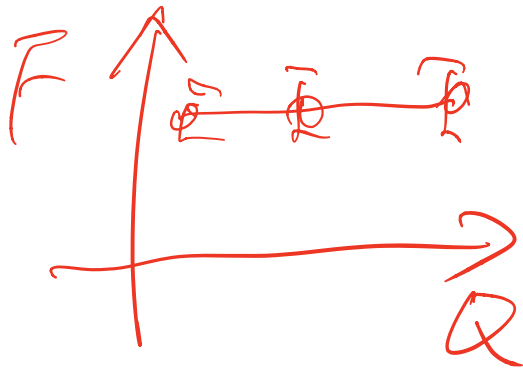
magnetic moment

$$\frac{\text{meson-baryon } \sigma}{\text{baryon-baryon } \sigma} =$$

Forbidden  $\phi \rightarrow \rho \pi$

1969. SLAC

$$e + N \rightarrow e + X$$




Feynman, Björken / Paschos

'parton model'

?


Assuming partons are quarks.

$$\pi^0 \rightarrow \gamma\gamma$$


$N_c$

$$\sigma \sim N_c^2$$

(9) 4 ✓

$$e^+e^- \rightarrow \text{hadrons}$$


$\sigma \sim N_c$

Questions:

$$\frac{g^2}{4\pi} \sim 14 \quad \text{strong}$$

Higgs scaling weak

$SU(3)$  3 real?

8 real?

1954. Yang-Mills theory

$$L_{YM} = -\frac{1}{4} F_{\mu\nu}^a F^{\mu\nu a} \quad \partial_\mu A_\nu - \partial_\nu A_\mu + g A A$$

$$- \bar{\psi} \gamma_\mu (\partial^\mu - i g T \cdot b^\mu) \psi$$

$\begin{pmatrix} n \\ p \end{pmatrix}$

$\xrightarrow{SU(2)}$  gauge boson

Massless gauge bosons.

Quantization?



Renormalization?

Feynman. played with it

gravity [Quantum of

1967 Faddeev & Popov.

ghost method.

perturbative calculation.

Apply YM to weak

Feynman theory.  $\bar{\psi}_1 \gamma^\mu P_L \psi_2$

EFT

$\bar{\psi}_3 \gamma^\mu P_L \psi_4$

Non-renormalizable

Non-Unitarity

1964 Englert - Brout

Higgs

Guralnik - Hagen-Kibble.

1967. Weinberg - Salam.

1971, 72. 't Hooft, Veltman  
proved. Ren. Uni.

1973. YM to strong.

Parti, Salam.

Fritzsch, Gell-Mann

Leutwyler.

Weinberg

Quarks  $\leftarrow$  gluons.

1973. Charge. Ren.

Gross. Wilczek. Politzer

Asymptotic freedom



1969. Kriplovich.

  $\pi_{uv}$  Coulomb gauge  
 $\alpha_s$   X

1972. it ~~is~~ ~~not~~ , Not published

1974.

Collider.

precision test of  $\alpha_s$   
gluon jets.