QCD

Up to now, we have discussed a general gauge theory. QCD in particular is an SU(3) gauge theory with six sets of quark fields:

	e_q		
"up type"	u $\frac{2}{3}$ $m_u \sim 3$ MeV	c $\frac{2}{3}$ $m_c \sim 1{,}2$ GeV	t $\frac{2}{3}$ $m_t \sim 172$ GeV
"down type"	d $-\frac{1}{3}$ $m_d \sim 5$ MeV	s $-\frac{1}{3}$ $m_s \sim 100$ GeV	b $-\frac{1}{3}$ $m_b \sim 4{,}6$ GeV

Each fermion transforms under the fundamental rep. of color: eg. $u = \begin{pmatrix} u_1 \\ u_2 \\ u_3 \end{pmatrix}$ "red" "green" "blue"

The associated gauge field is called gluon.

The heavier quarks decay because of the weak interation.

2.4 A brief history of the discovery of QCD

- 50's: "Particle Zoo": a very large number of hadrons are discovered. Attempts to develop a field theory of the strong interaction all fail. Among those failed attempts:

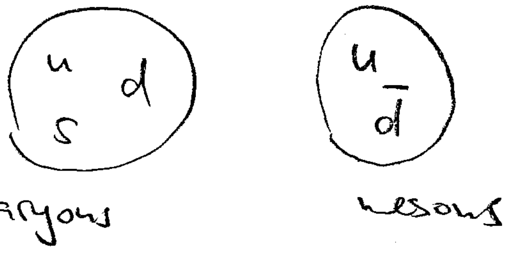
- '54: Yang-Mills propose non-abelian gauge theory (seems to imply new unobserved massless particle)

Dyson '60: "The correct theory will not be found in a hundred years!"

General believe that QFT does not work for strong interactions

- '64 Quark model (Gell-Mann, Zweig)

Hadrons look like they are made from hypothetical quarks



'65 Additional quantum number "color"

$$\Delta^{++} \sim | u\uparrow, u\uparrow, u\uparrow \rangle \ ?$$

spin 3/2

cannot be in the same state (Pauli exclusion)

must be anti symm with respect to exchange of quarks

Work if we introduce three "colors" of each quark flavor and ask that all hadrons are color neutral
(Han, Nambu, Greenberg ; Bogolyubov, Struminski, Tavchelidze)

Late 60s $e^- p \to e^- X$ scattering exp's at SLAC

can be explained by assuming that the electrons scatter elastically on <u>free</u> constituents ("partons") of the proton

Feynman: "We shall ... think of the incoming proton as a box of partons sharing the momentum and practically free"

Parton model . parton - parton interactions should become weak at high energies "asymptotic freedom".

'68 Callan & Gross show a way of distinguishing the spin of the partons. Exp strongly favors spin $1/2$.

'71 't Hooft & Veltman show that YM theories are renormalizable

'72 Gell-Mann & Fritzsch propose SU(3) gauge theory with quarks and gluons (at a conference). In '73 paper with Leutwyler they explain the advantages of this model.

'73 Politzer; Gross & Wilczek show that YM theory is asymptotically free !

(Gross and Wilczek set out to proof that <u>no</u> field theory is asymptotically free - YM is the only exception)