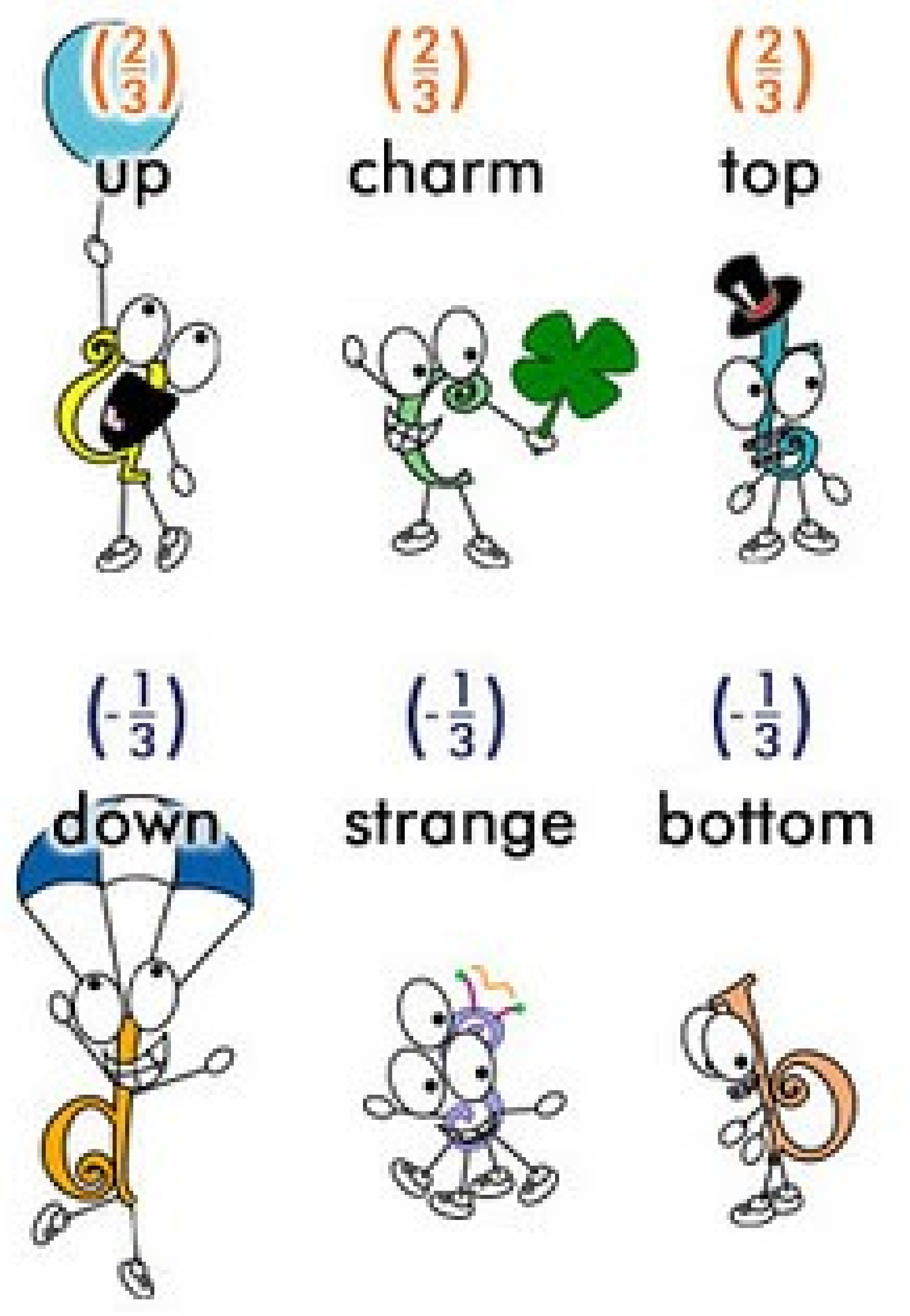
The standard model

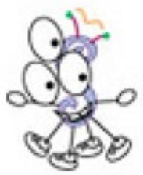
PART 3 by Sandra Burkutean

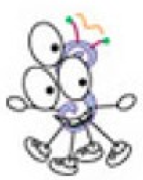
Quarks



source google pictures

Quark masses and uds flavour symmetry

m() > m()

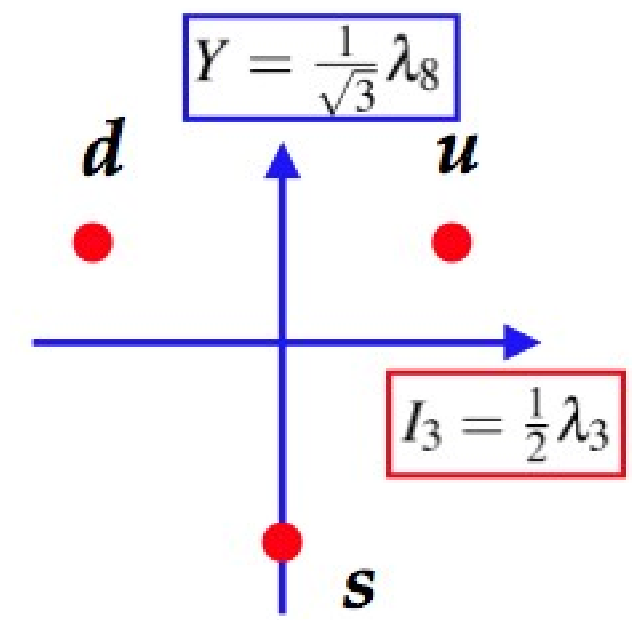
m() > m()

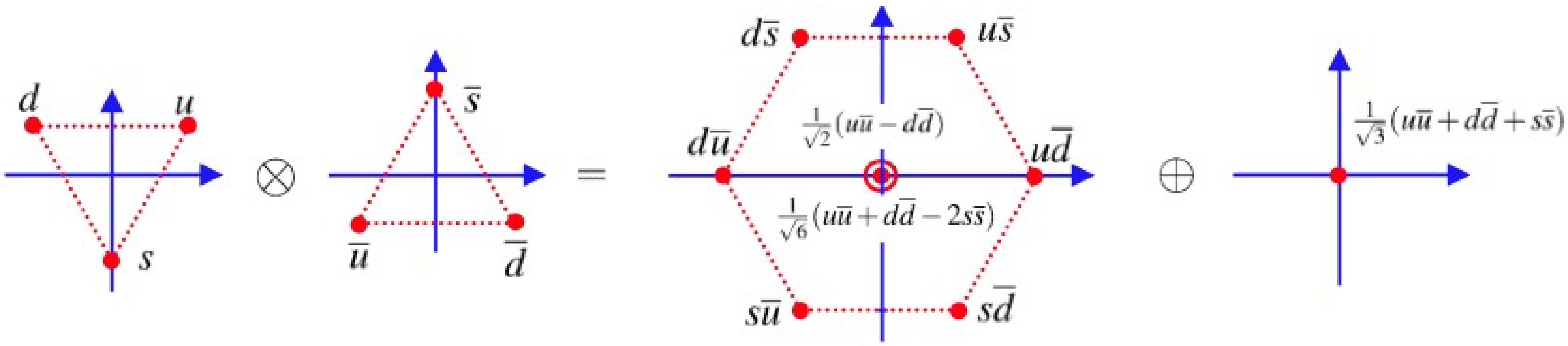
Hence the symmetry between up, down and strange quarks is not exact

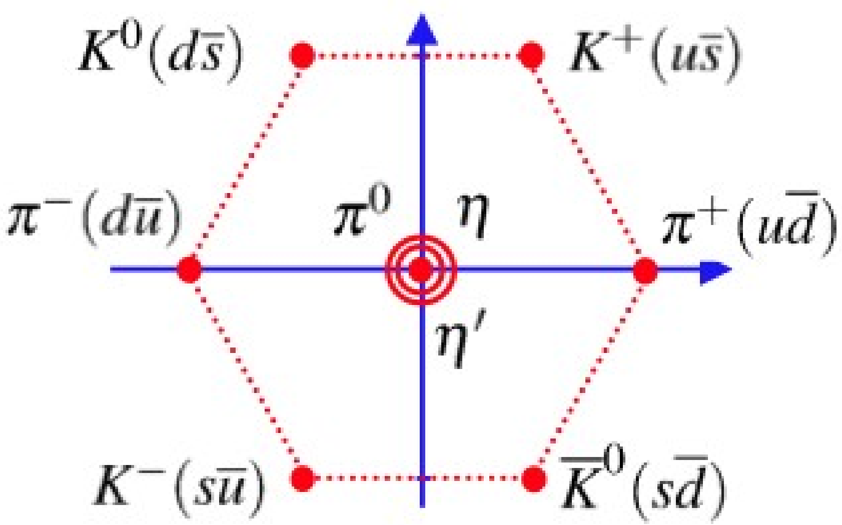
The flavour symmetry implies that there exists a unitary matrix such that :

$$\begin{pmatrix} u' \\ d' \\ s' \end{pmatrix} = \hat{U} \begin{pmatrix} u \\ d \\ s \end{pmatrix} = \begin{pmatrix} U_{11} & U_{12} & U_{13} \\ U_{21} & U_{22} & U_{23} \\ U_{31} & U_{32} & U_{33} \end{pmatrix} \begin{pmatrix} u \\ d \\ s \end{pmatrix}$$

$$\vec{T} = \tfrac{1}{2}\vec{\lambda} \qquad \hat{U} = e^{i\vec{\alpha}.\vec{T}}$$

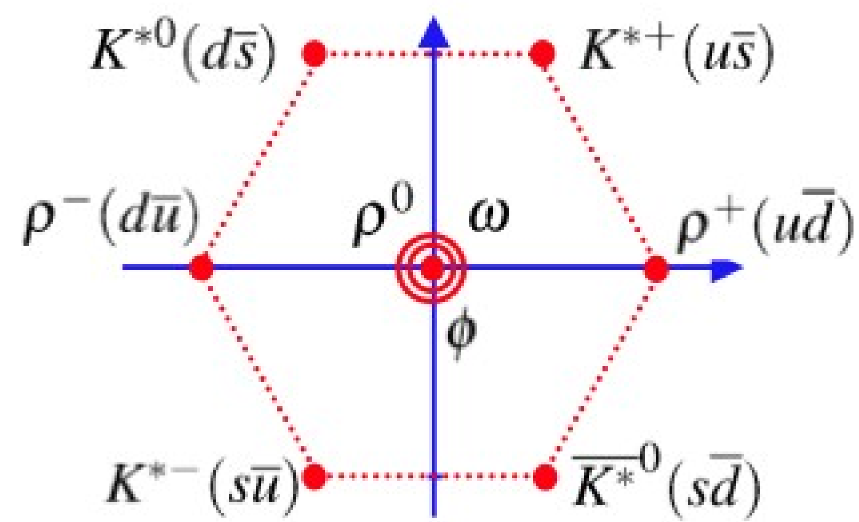






Pseudoscalar mesons

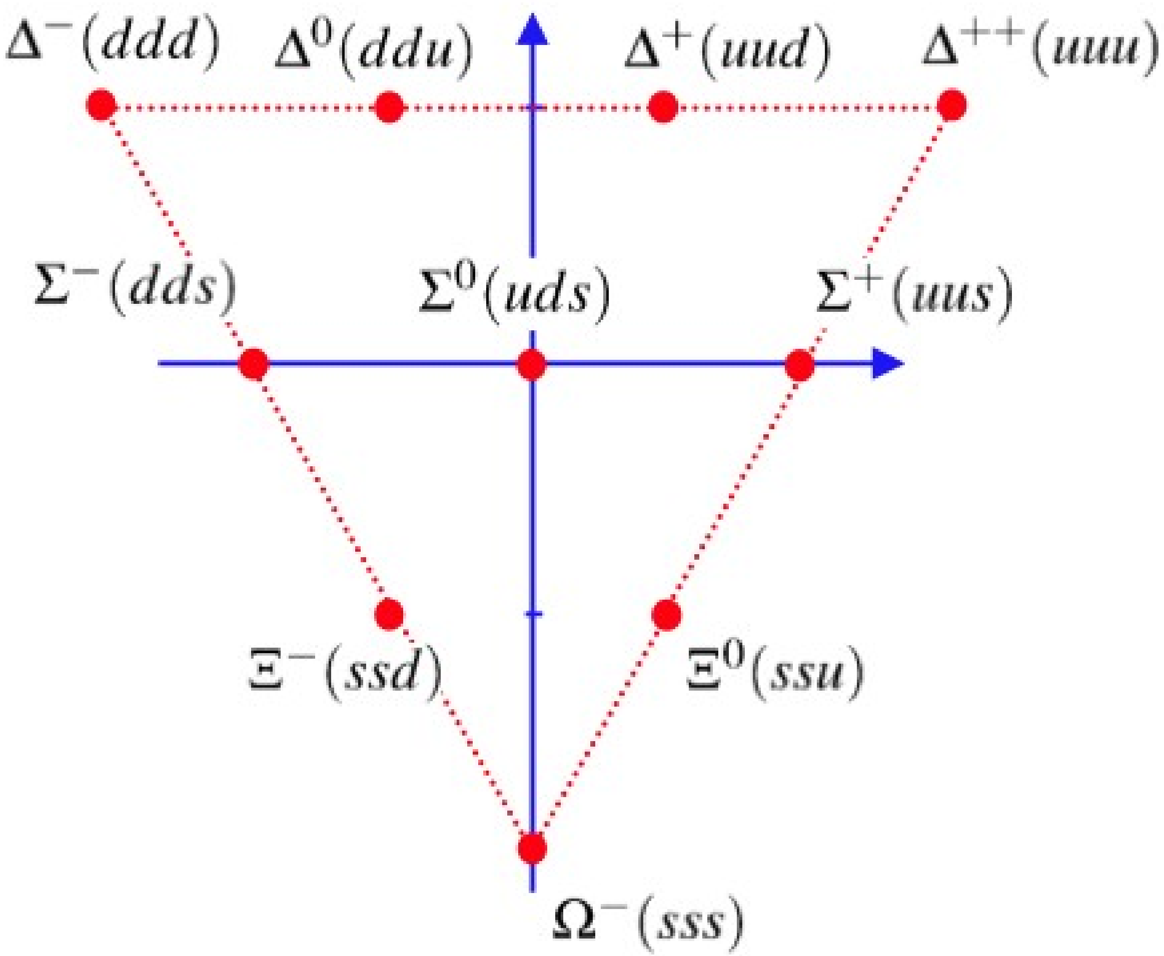
L = 0
S = 0
J = 0
P=-1



Vector mesons

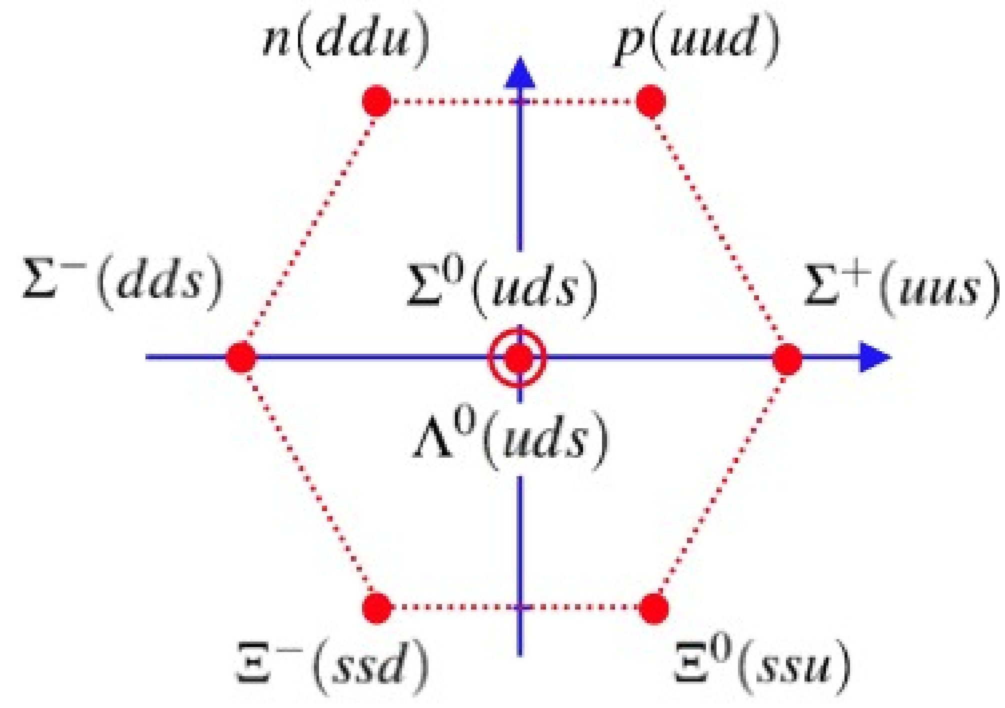
L = 0
S = 1
J = 1
P = -1

Figures taken from Prof. M.A. Thomsons's, Michaelmas 2010 lecture



Baryon decouplet

L = 0
S = 3/2
J = 3/2
P = +1



Baryon Octet

L = 0
S = 1/2
J = 1/2
P = +1

Figures taken from Prof. M.A. Thomsons's, Michaelmas 2010 lecture notes

Quantum Chromodynamics (QCD)

Invariance under SU(3) local phase transformation

suppose we know the Gell-Mann matrices, then we can construct a transformation of the form:

$$\psi \longrightarrow \psi \exp(i\,\lambda\,.\Theta(x))$$

vector in colour space

8 Gell-Mann matrices

8 spin-1 gauge bosons

quarks carry colour charge (red, green, blue)

anti - quarks carry anti-charge

Due to the SU(3) symmetry, the strong interaction is the same for all three colours

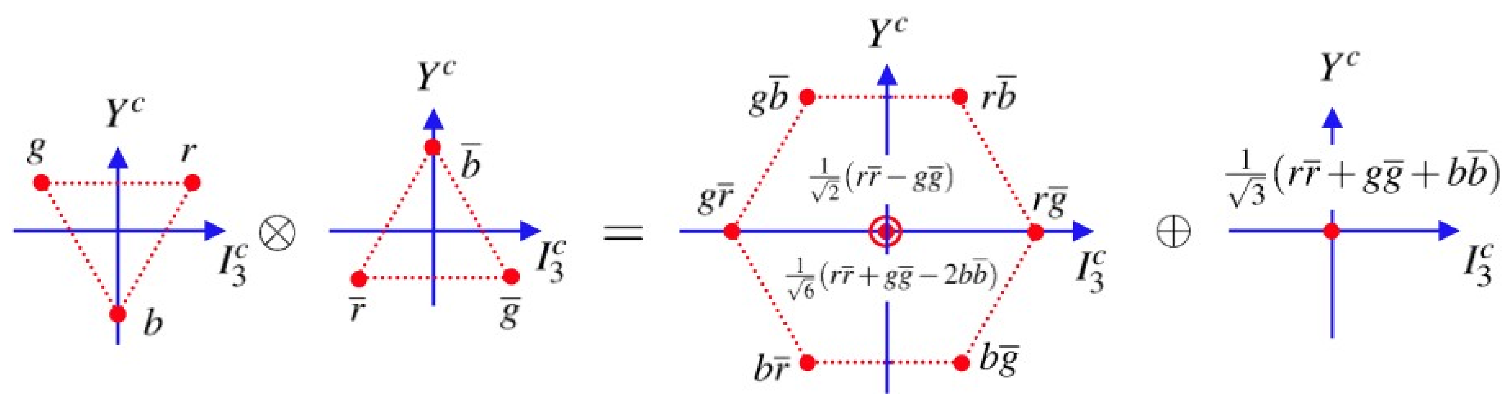
ONLY COLOUR SINGLET STATES EXIST(colour confinement)

colour quantum numbers yield zeros

invariant under SU(3) transformations

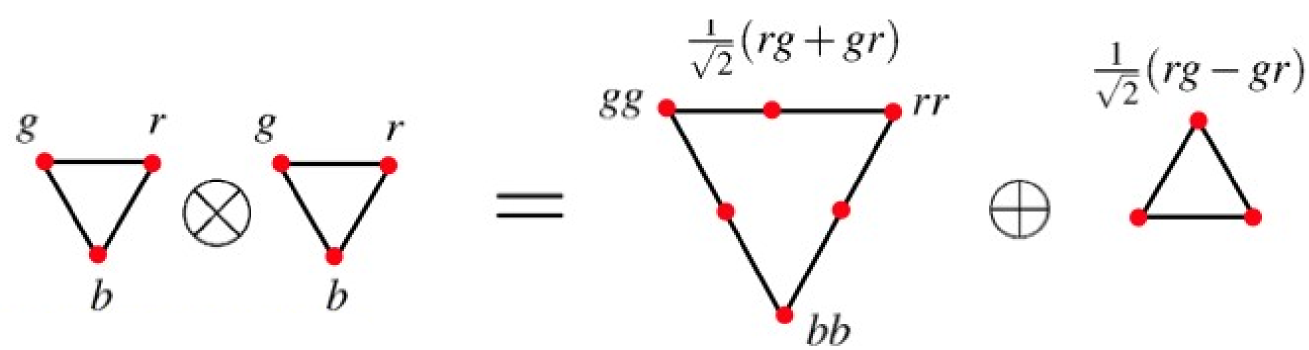
ladder operators yield zero

$q\bar{q}$



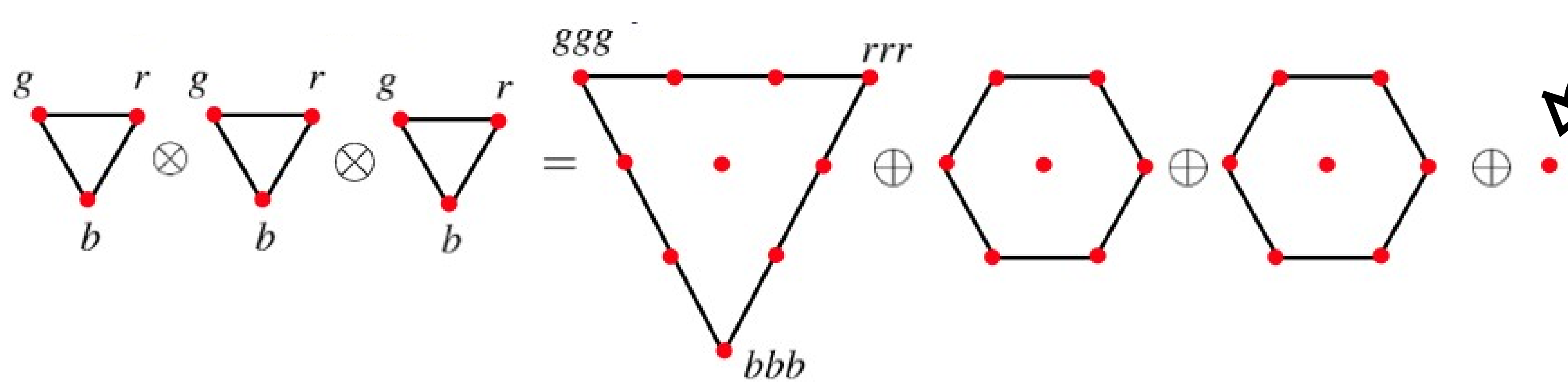
MESONS

qq



BARYONS

qqq



Figures taken from Prof. M.A. Thomsons's, Michaelmas 2010 lecture notes

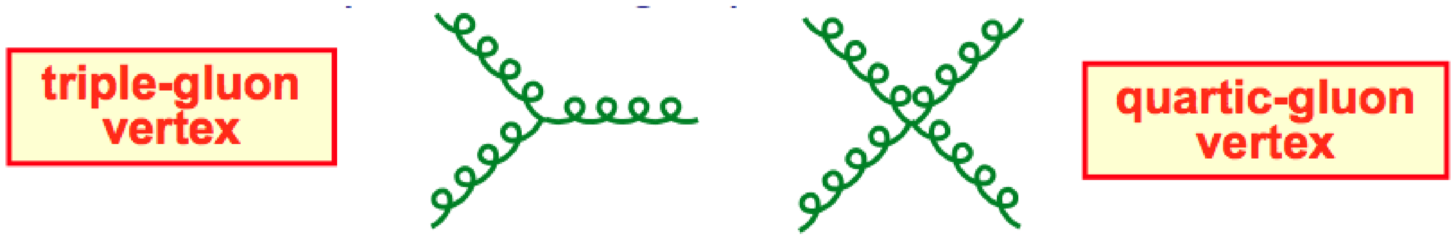
Gluons

Since gluons carry colour charge, there are 9 states they could potentially exist in:

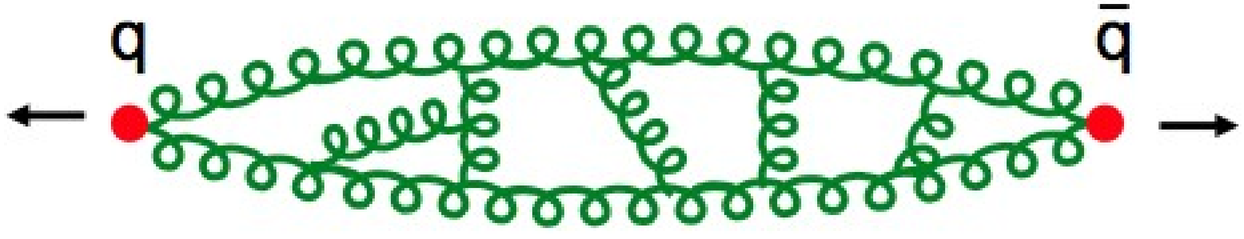
octet + 1 colourless singlet

this would behave like a photon ---- not observed
the strong force is short range !!!!
SU(3) symmetry

Gluon-gluon interactions

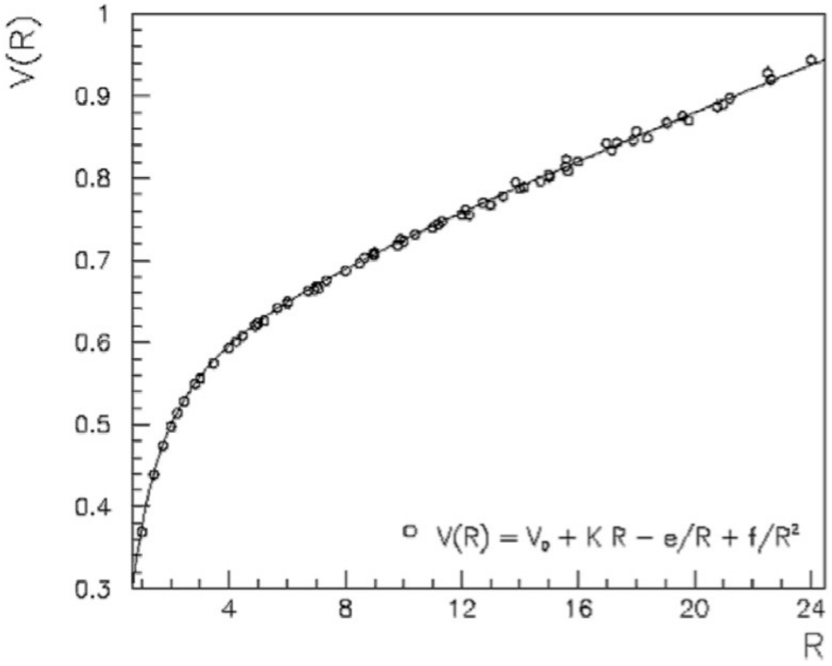


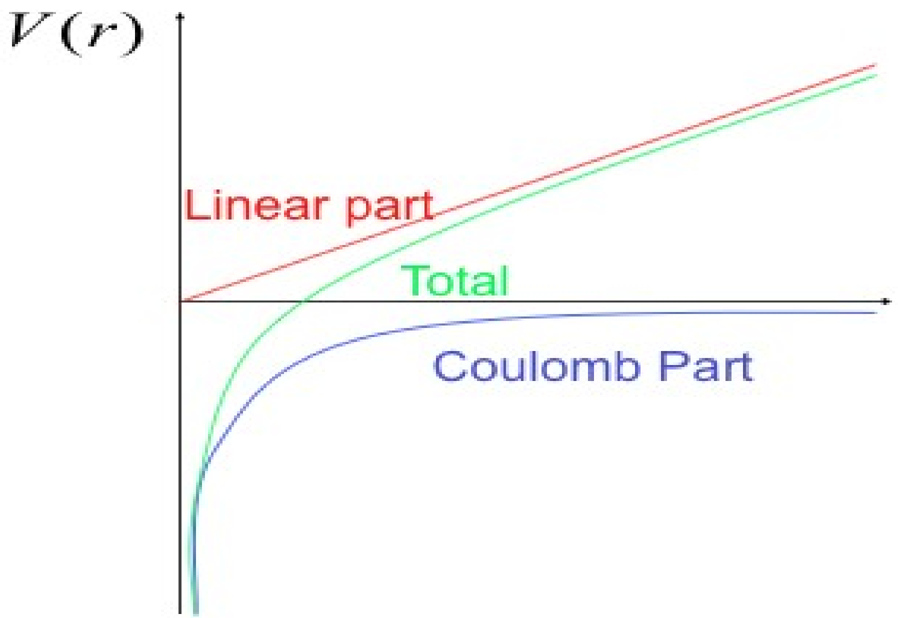
flux tubes



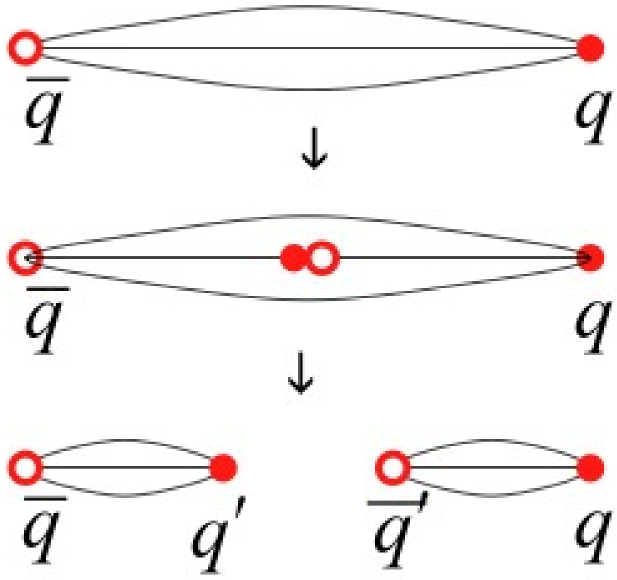
Figures taken from Prof. M.A. Thomsons's, Michaelmas 2010 lecture notes

Hadronisation





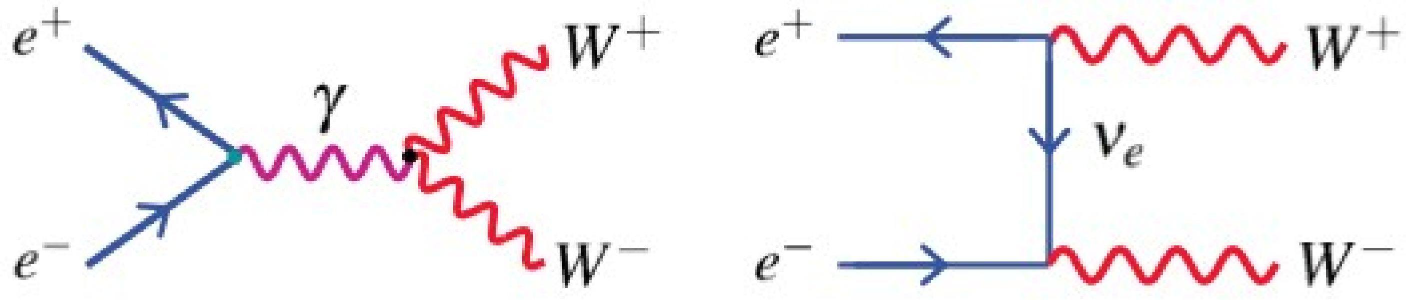
$$V(r) = -\frac{4}{3}\frac{\alpha_s}{r} + \kappa r \approx -\frac{0.13}{r} + r \quad (\text{for } \alpha_s \approx 0.5, \text{r in fm and V in GeV})$$

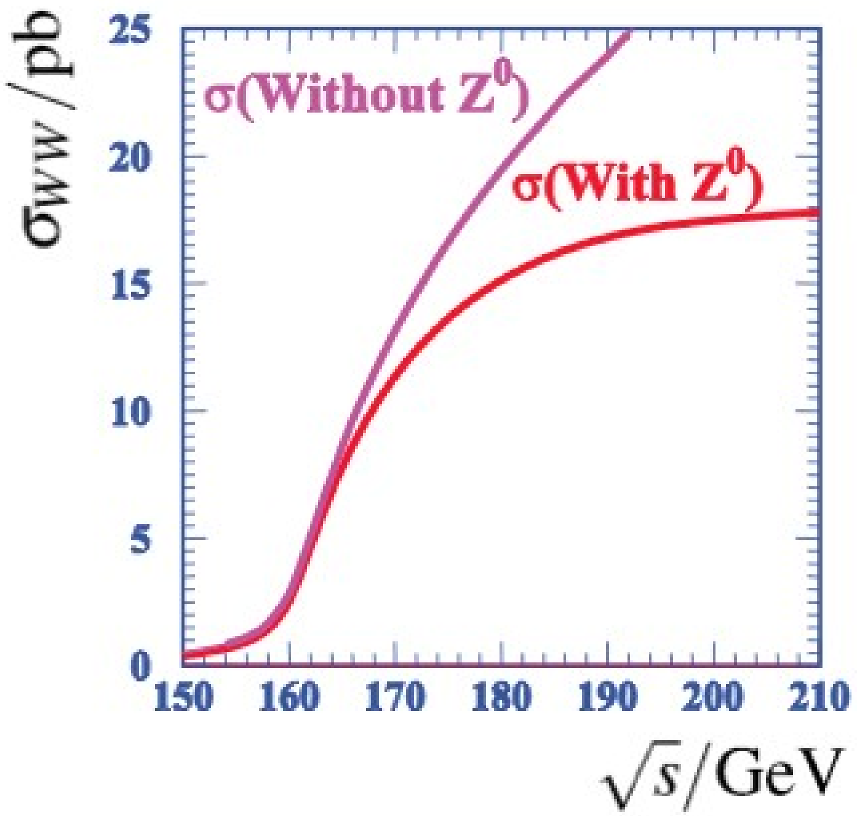


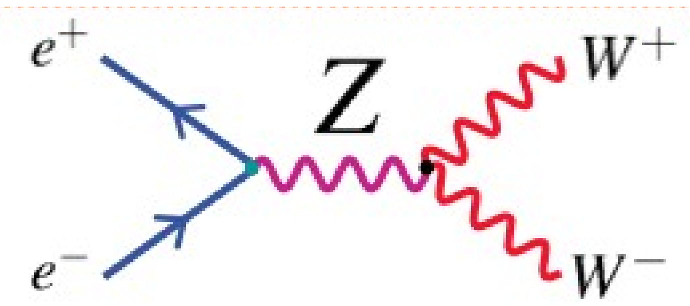
Figures taken from Peter Richardson , IPPP Durham lecture co

Electroweak Unification

Why do we need this ?







Figures taken from Prof. M.A. Thomsons's, Michaelmas 2010 lecture r

SU(2) * U(1)

place fermions in isospin doublets

$\psi \longrightarrow \psi \exp(i\, \alpha(x).\, \sigma/2)$

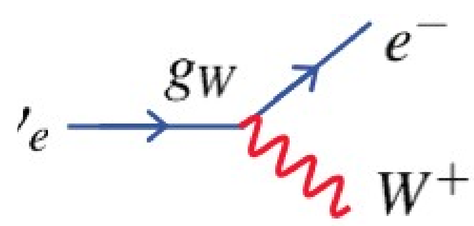
3 gauge bosons

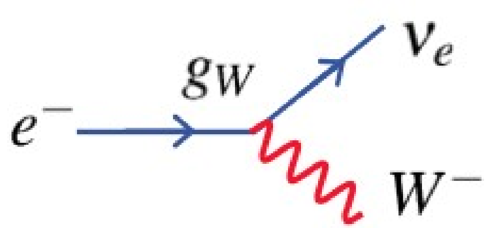
3 Pauli spin matrices

2 charged current interactions

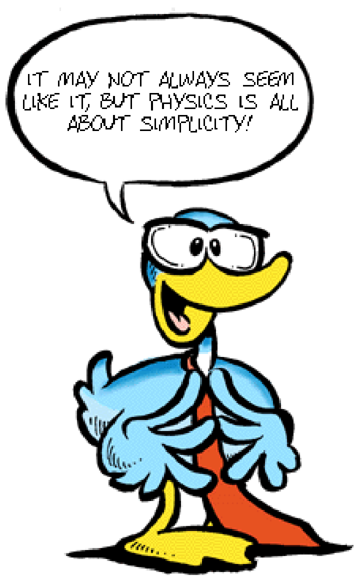
1 neutral current interaction

r combination of
1 and W2 gives





There are two spin 1
utral gauge bosons availab

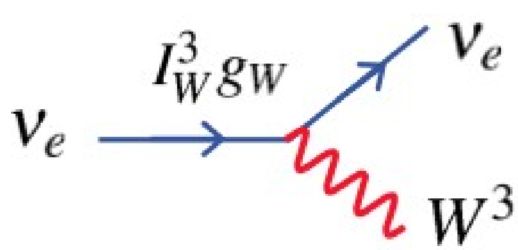


linear combination in terms
of a weak mixing angle

ɣ

Z

Figures taken from Prof. M.A. Thomson's, Michaelmas 2010 lecture notes



This is a new U(1) gauge symmetry, consv. of hypercharge

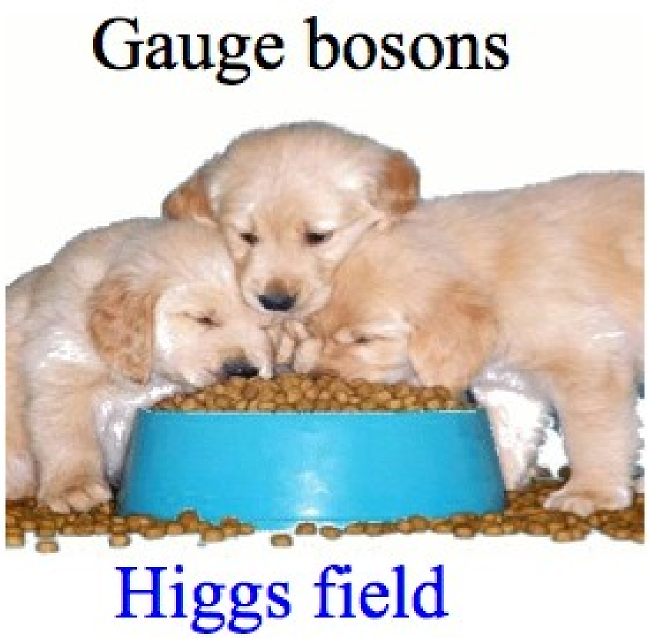
$$A_\mu = B_\mu \cos\theta_W + W_\mu^0 \sin\theta_W$$

$$Z_\mu^0 = -A_\mu \sin\theta_W + W_\mu^0 \cos\theta_W$$

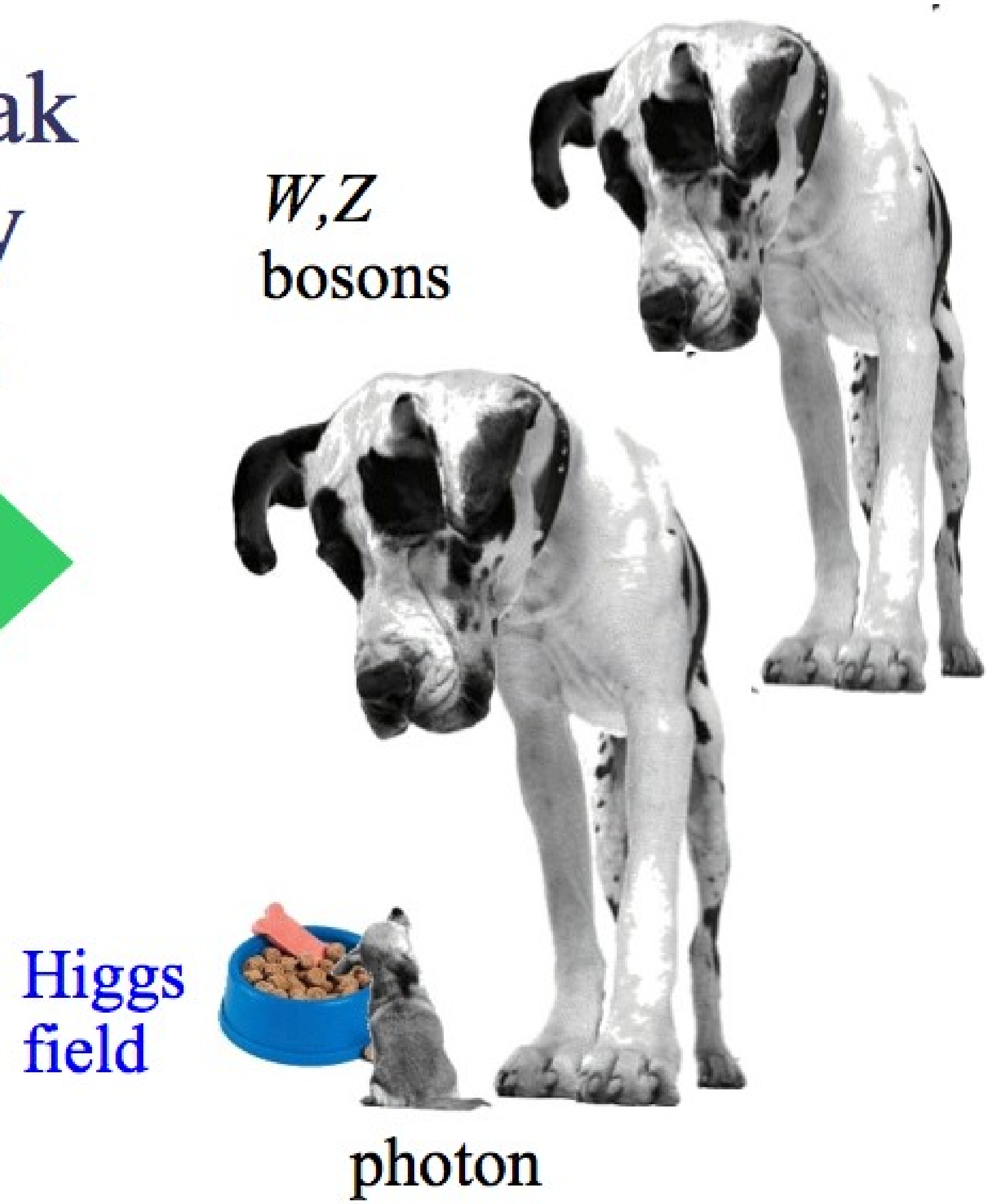
The previous steps only work for massless gauge bosons
(like the photon) !!!

propose a scalar field

with non-zero vacuum expectation value



Electroweak symmetry breaking



80.4 GeV

91.2 GeV

Idea and pictures taken from Rheinhard Schwienhorst, University of Virginia Physics Colloquium, 11/2/2007

Problems with the standard model

1. Too many free parameters

2. Why does nature choose these particular symmetries ?

3. Where does the matter/anti-matter discrepancy come from ?

4. How can we incorporate gravity ?