Evidence for Color

The low lying baryon states are symmetric with respect to the interchange of the quark flavor and spin indices. Consider for example, Δ^{++} resonance and Ω^-. Since $J = 3/2$, it is easily seen that spin wave function is

$\chi(\uparrow\uparrow\uparrow)$ = symmetric. Thus the combined spin and flavor wave function is:

$$|\Delta^{++}, J = 3/2\rangle = |u\uparrow u\uparrow u\uparrow\rangle$$

$$|\Omega^-, J = 3/2\rangle = |s\uparrow s\uparrow s\uparrow\rangle$$

which are symmetric. This would imply that the total spin, flavor, and space wavefunctions are symmetric.

Since quarks are fermions, they must obey Fermi-Dirac statistics and their total wave function must be antisymmetric. The proposal and Han + Nambu was that there is another hidden quantum number called "color" which can assume three values Red, Green and Blue. With the help of these three we may construct a totally antisymmetric wave function.

$$|q_A q_B q_C\rangle = \frac{1}{\sqrt{6}} \epsilon_{abc} \left(|q_A^a q_B^b q_C^c\rangle\right)$$

where A, B, C refers to quark flavor and a, b, c refer to quark color. The three colors are the triplet representation of $SU(3)_c$; from the triplet one can construct a singlet, octets, and a decuplet:

$$3 \otimes 3 \otimes 3 = 1 \oplus 8 \oplus 8 \oplus 10$$

The singlet we shall call <u>white</u>. From

$$\left(3 \otimes \bar{3}\right)_c = 1 \oplus 8$$

We can see why $q\bar{q}$ states are the only ones observed (they belong to 1 = singlet). While

$$3 \otimes 3 = 6 \oplus \bar{3} \quad \text{is colored.}$$

From a diquark state and four quark state, one cannot form a color singlet state.

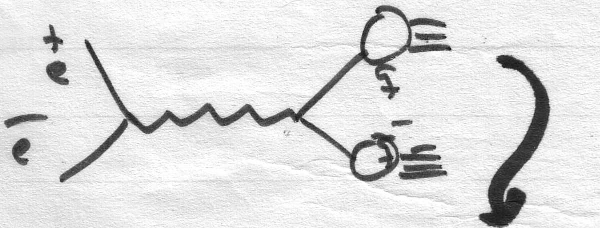
For meson, $q\bar{q}$, the wave function is.

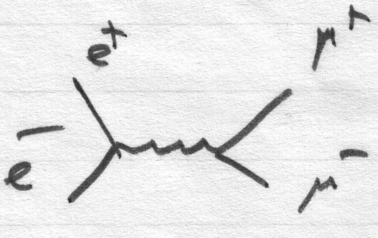
$$|q_A \bar{q}_B\rangle = \frac{1}{\sqrt{3}} \left| q^r_A \bar{q}^r_B + q^b_A \bar{q}^b_B + q^g_A \bar{q}^g_B \right\rangle$$

The confinement postulate states that all hadrons and physical observable states are color singlets.

Evidence for color :

1) $e^+e^- \longrightarrow$ hadrons





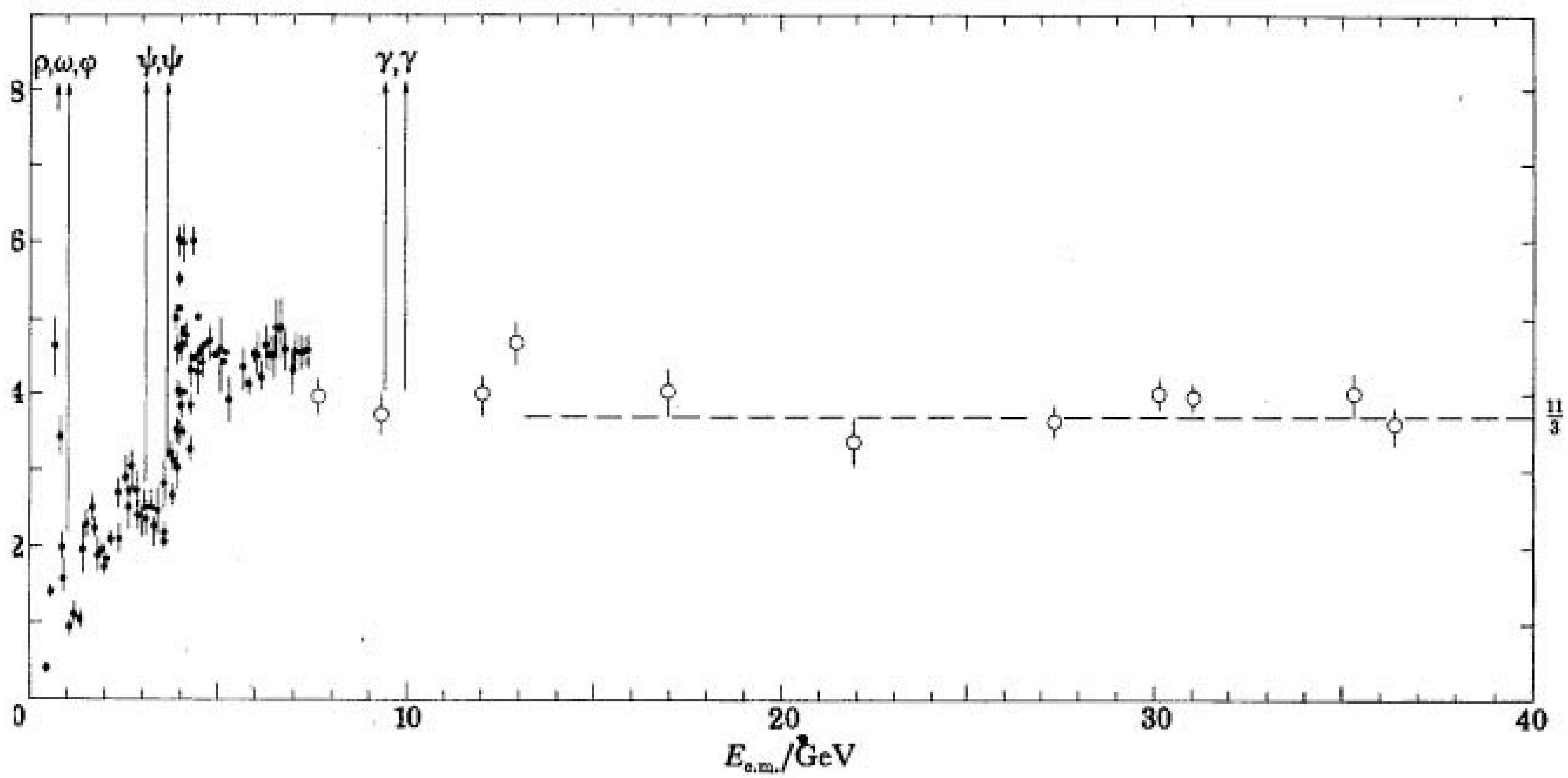
$$R(s) = \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)} = \sum Q^2$$

$$R = n_c\left[(Q_u)^2 + (Q_d)^2 + (Q_s)^2\right] = n_c\left[\left(\tfrac{2}{3}\right)^2 + \left(\tfrac{-1}{3}\right)^2 + \left(-\tfrac{1}{3}\right)^2\right]$$

$$= \tfrac{2}{3}\, n_c$$

$n_c \equiv$ # of colors

Experimentally, $R \simeq 2 - 2.5$ for $\sqrt{s} = 2 - 3.8$ GeV. which is in good agreement with the results we obtained for $N_c = 3$.



ρ,ω,φ
ψ,ψ
γ,γ
8
6
4
2
0
10
20
30
40
$\frac{11}{3}$
$E_{c.m.}$/GeV