(2) **LHC (Large Hadron Collider)**

\[ P \quad E \equiv p \equiv 7 \text{ TeV} \quad 10^{12} \text{ eV} \]

\[ \uparrow \quad \text{a u quark} \quad \uparrow \quad \text{a \bar{u} quark} \]

*sometimes, matter + antimatter meet, even though to the casual observer, it's a matter/antimatter collider!*

(3) **The GLUE**

Quarks like ball bearings in "gelatin" called (≈1970)

the "glue" (What is it???)

Ground state of Gluons (photon analog)

(photon - neutral (e+e-)) (gluon - (color) charged)

How... imagine trying to pull a quark out of a nucleon
Terminology:

Baryon: 3 quarks (valence) (Antibaryon 3 antiquarks)

Meson: 1 quark 1 antiquark always unstable

1 Baryon (the Proton) is stable, the rest unstable.

Given a choice of quarks/antiquarks, still must specify total angular momentum (spin + orbital)

Proton/Neutron: $L = 0$ (no orbital)

Spin: $\uparrow \uparrow \downarrow$

3 spin-$\frac{1}{2}$ --- which one?

\[ \uparrow \uparrow \downarrow \] gets into Pauli Principal Issues

\[ \uparrow \uparrow \downarrow \] later.
increasing "energy"

energy kind of linear with distance (but not fundamental)

"INFRARED SLAVERY"

but quark/antiquark pairs always around

"pop"

nucleon

MESON.
In the 1950's a third quark (s for strange) was discovered
\[ m_s \approx 120 \text{ MeV} \] in nucleon

\[ \text{spin } -\frac{1}{2} \] Baryons (with strangeness)

\( s \) quark \(-1\) unit of "strangeness"

\( \bar{s} \) quark \(1\) unit of strangeness (ack!)

**Baryon Octet**

\( J = \frac{3}{2} \), Decuplet...

\( \Sigma^+ \) is not antiparticle of \( \Sigma^- \)

\( \Sigma^0 + \Lambda \) no Pauli principle problems
Mesons

\[ \begin{array}{ccc}
  J=0 & L=0 & \text{spin} \\
  & & J=1 \uparrow \ \\
\end{array} \]

\[ \begin{array}{ccc}
  u \bar{u} & \rightarrow & \pi^0 \\
  d \bar{d} & \rightarrow & \eta \\
  u \bar{d} & \rightarrow & \pi^+ \\
  d \bar{u} & \rightarrow & \pi^- \\
\end{array} \]

\[ \begin{array}{ccc}
  M_c^2 \sim 140 \text{ MeV} & 770 \text{ MeV} \\
\end{array} \]

WOW!

\[ \begin{array}{ccc}
  s \bar{s} & \rightarrow & \eta' \ \\
  u \bar{s} & \rightarrow & K^+ \\
  d \bar{s} & \rightarrow & K^0 \\
  \bar{u} \bar{s} & \rightarrow & K^+ \\
  \bar{d} \bar{s} & \rightarrow & \bar{K}^0 \\
\end{array} \]

add \( L \neq 0 \)... Big Fun!

"Meson Spectroscopy"