

# The Big Particle Picture

**Quarks**  
 up charm top (2/3 charge)  
 down strange bottom (-1/3 charge)  
 with corresponding anti-quarks (-2/3 & 1/3)

Proton [u u d] ( $2/3 + 2/3 + -1/3 = +1$ )  
 Neutron [d d u] ( $-1/3 + -1/3 + 2/3 = 0$ )  
 Anti-proton [ $\bar{u}\bar{u}\bar{d}$ ] ( $-2/3 + -2/3 + 1/3 = -1$ )  
 Ant-neutron [ $\bar{d}\bar{d}\bar{u}$ ] ( $1/3 + 1/3 + -2/3 = 0$ )

**Leptons**  
 electrons } (electrically charged)  
 muons }  
 taus }  
 corresponding neutrinos

When quarks combine, they form hadrons (which must be color neutral)

**Force carrier particles**  
 photon → EM force  
 gluon → strong force  
 Z } weak force  
 W<sup>+</sup> } (radioactive decay)  
 W<sup>-</sup> }

**Baryons**  
 3 quarks  
*net integer charge*

**Mesons**  
 quark and antiquark  
*net integer charge*

**Quantum Numbers**  
 electric charge → +1, 0, -1  
 color charge → quarks – 3 choices; gluons – 8 choices;  
 hadrons – neutral; leptons no charge  
 flavor → tells what type of quark or lepton it is  
 spin → (0, 1/2, 1, 3/2) x ħ . . .

**Fermions**  
*odd 1/2 integer spin*  
 quarks  
 leptons  
 baryons  
 nuclei with odd number of nucleons

**Bosons**  
*integer spin*  
 all force carrier particles  
 mesons  
 nuclei with even number of nucleons