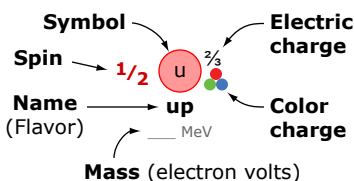


Particles

Everything is made of particles.



- Antiparticles.** Each particle has an antiparticle with the same mass and spin, but opposite charge.
- Mixtures.** Some elementary particles are mixtures (linear superpositions) of other elementary particles.

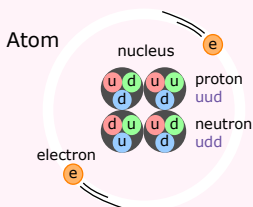
Hypothetical. Postulated particles that many physicists expect will be discovered.

- Spin.** Spin is a quantum property of particles. Bosons have integer spin. Fermions have half-integer spin. A particle with non-zero spin has left- or right-handed chirality.
- Electric Charge.** Each particle has positive, negative, or zero electric charge.
- Color Charge.** A quark has one of three color charges called red, green, or blue. An anti-quark has an anti-color. A gluon has a color and an anti-color.

Elementary Particles

This shows all the elementary particles in the standard model (SM) of particle physics plus some hypothetical particles.

Fermions half-integer spin $1/2, 3/2$
Matter is made of fermions.
 Fermions obey the exclusion principle.



Standard Fermions

	generation		
spin	I	II	III
Quarks 1/2	up 1.7-3.1 MeV	charm 1.1-1.4 GeV	top 171-175 GeV
	down 4.1-5.7 MeV	strange 80-130 MeV	bottom 4.1-4.4 GeV
	electron 511 keV	muon 106 MeV	tau 1.8 GeV
	electron neutrino <1 eV?	muon neutrino <1 eV?	tau neutrino <1 eV?
	Leptons 1/2		

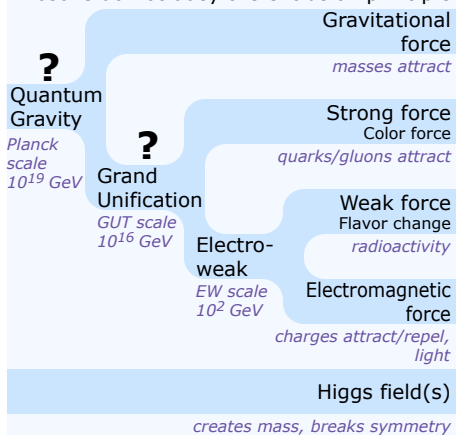
Supersymmetry (SUSY) theory proposes a partner boson for each fermion and a partner fermion for each boson.

Superpartner Bosons — Sfermions

	generation		
spin	I	II	III
Squarks 0	sup 1/2	scharm 1/2	stop 1/2
	sdown 1/2	sstrange 1/2	sbottom 1/2
	selectron 0	smuon 0	stau 0
	electron sneutrino 0	muon sneutrino 0	tau sneutrino 0
	Sleptons 0		

Bosons

integer spin 0 1 2
Forces are carried by gauge bosons.
 Bosons do not obey the exclusion principle.



Standard Bosons

spin	Gauge Bosons Force Carriers		Scalar Bosons
2	graviton massless	Gravitational force	
1	gluon massless	Strong force	
1	W_i massless	Weak force	
1	Z 80 GeV 91 GeV	Weak force	
1	photon massless	Electromagnetic force	
0	Higgs 124-127 GeV	Higgs field	

Superpartner Fermions

spin	Gauginos		Scalar Bosons
3/2	gravitino		
1/2	gluino		
1/2	wino	zino	neutralino
1/2	bino	photino	chargino
1/2	Higgsino	neutralino	

Unified forces split by symmetry breaking.

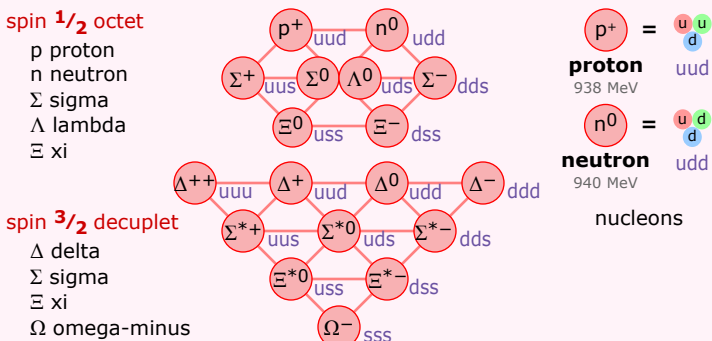
Other elementary particles may yet be discovered. **String theory** proposes that all elementary particles are actually tiny vibrating strings.

Composite Particles — Hadrons

Composite particles are composed of two or more elementary particles. This shows some of the hundreds of known composite particles.

Composite Fermions — Baryons

Baryons are fermions composed of three quarks. This shows only the baryons made of u, d, and s quarks.



Composite Bosons — Mesons

Mesons are bosons composed of a quark and an antiquark. This shows only the mesons made of u, d, and s quarks.

