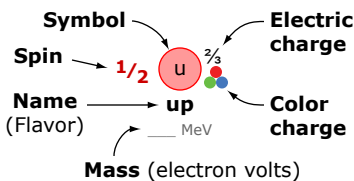


Particles

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.

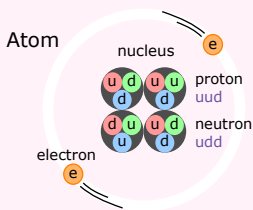
Elementary Particles

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

Spin	generation				
	I	II	III		
$1/2$	Quarks	up (u)	charm (c)	top (t)	
		1.7-3.1 MeV	1.1-1.4 GeV	171-175 GeV	
		down (d)	strange (s)	bottom (b)	
		4.1-5.7 MeV	80-130 MeV	4.1-4.4 GeV	
	$1/2$	Leptons	electron (e^-)	muon (μ^-)	tau (τ^-)
			511 keV	106 MeV	1.8 GeV
		electron neutrino (ν_e)	muon neutrino (ν_μ)	tau neutrino (ν_τ)	
		< 2 eV	< 190 keV	< 18 MeV	

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

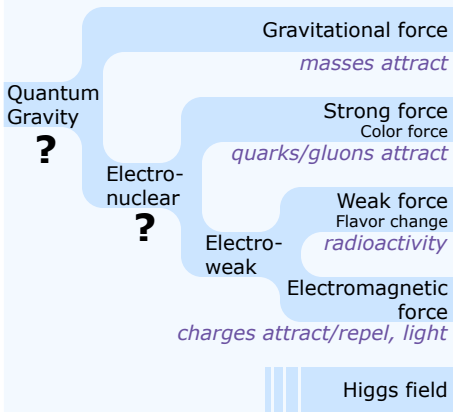
Superpartner Bosons — Sfermions

Spin	generation				
	I	II	III		
0	Squarks	sup (\tilde{u})	scharm (\tilde{c})	stop (\tilde{t})	
		$2/3$	$2/3$	$2/3$	
		sdown (\tilde{d})	sstrange (\tilde{s})	sbottom (\tilde{b})	
		$-1/3$	$-1/3$	$-1/3$	
	0	Sleptons	selectron (\tilde{e})	smuon ($\tilde{\mu}$)	stau ($\tilde{\tau}$)
			$1/2$	$1/2$	$1/2$
		electron sneutrino ($\tilde{\nu}_e$)	muon sneutrino ($\tilde{\nu}_\mu$)	tau sneutrino ($\tilde{\nu}_\tau$)	
		$1/2$	$1/2$	$1/2$	

Bosons

integer spin 0 1 2

Forces are carried by gauge bosons.



Bosons do not obey the exclusion principle.

Standard Bosons

Spin	Force Carriers
2	graviton (G) ? massless
1	gluon (g) massless
1	W$^\pm$, Z 80 GeV 91 GeV
1	photon (γ) massless
0	Higgs (H) ? 115-130 GeV

Superpartner Fermions

Spin	Force Carriers
$3/2$	gravitino (\tilde{G}) massless
$1/2$	gluino (\tilde{g}) massless
$1/2$	wino (\tilde{W}^\pm), zino (\tilde{Z}) 80 GeV 91 GeV
$1/2$	photino ($\tilde{\gamma}$) massless
$1/2$	Higgsino (\tilde{H}) 115-130 GeV

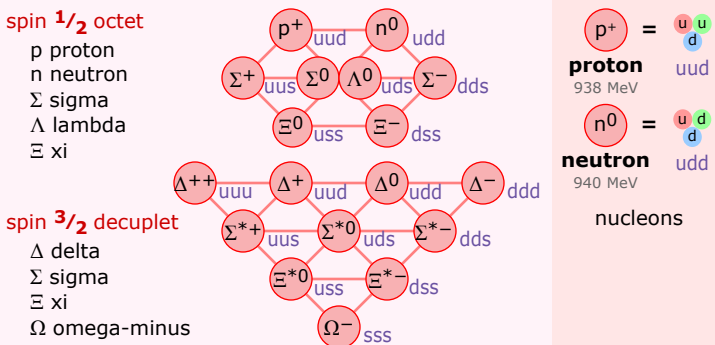
Other elementary particles may yet be discovered. **String theory** proposes that all elementary particles are actually tiny vibrating strings.

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.

