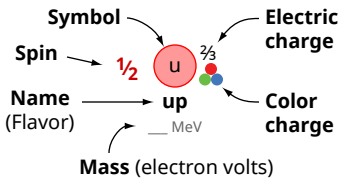
Particles

Everything is made of particles.

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.



A particle is a wave in a quantum field.

Antiparticles. Each particle has an antiparticle with the same mass and spin, but opposite charge. A particle with no charge may be its own antiparticle.

Mixtures. Some elementary particles are mixtures (linear superpositions) of other elementary particles.

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

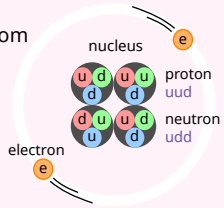
Elementary Particles

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

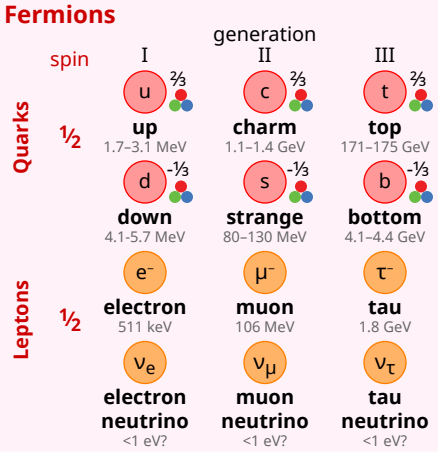
Fermions

half-integer spin ½ ³⁄₂

Matter is made of fermions.
Fermions obey the exclusion principle.



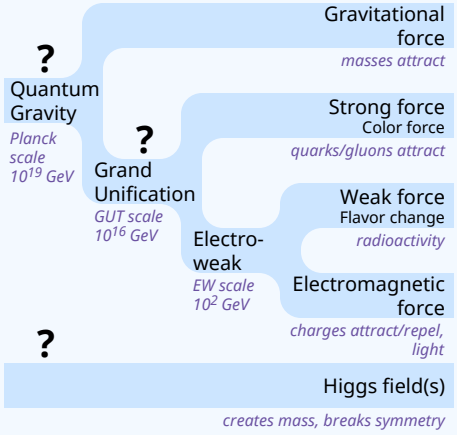
Fermions



Bosons

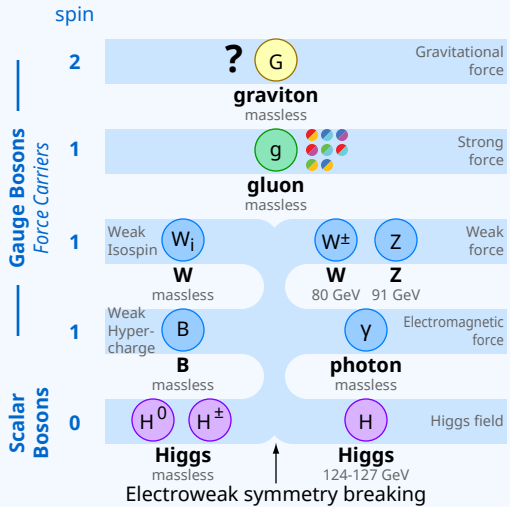
integer spin 0 1 2

Forces are carried by gauge bosons.
Bosons do not obey the exclusion principle.



Unified forces split by symmetry breaking.

Bosons



Electroweak symmetry breaking

? **Other elementary particles** may yet be discovered.
Dark matter may be elementary particles not yet discovered.

? **Light neutral scalar bosons** are postulated (for example, axions).
Supersymmetry (SUSY) proposes that every elementary particle has a superpartner.
String theory proposes that all elementary particles are tiny vibrating strings.

Composite Particles — Hadrons

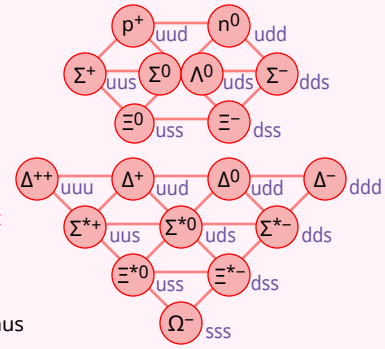
Composite particles are composed of two or more elementary particles. This shows some of the hundreds of known composite particles.

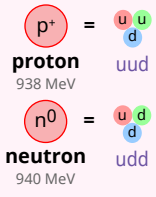
Composite Fermions — Baryons

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

spin ½ octet
- p proton
- n neutron
- Σ sigma
- Λ lambda
- Ξ xi

spin ³⁄₂ decuplet
- Δ delta
- Σ sigma
- Ξ xi
- Ω omega-minus





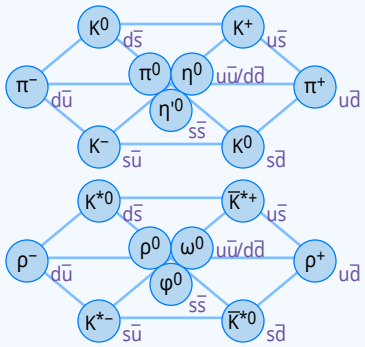
nucleons

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.

spin **0** nonet
- π pion
- η eta
- K kaon

spin **1** nonet
- ρ rho
- ω omega
- φ phi
- K kaon



Pions carry the nuclear force between nucleons.