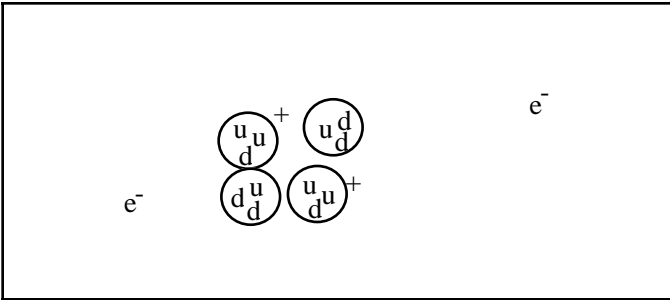


The Standard Model

	Scale	interact via
atoms	$\sim 10^{-10}$ m	electric fields (photons)
nucleons	$\sim 10^{-15}$ m	color (strong) force & electric fields (photons)
electrons	$< 10^{-18}$ m	electric fields (photons)
quarks	$< 10^{-18}$ m	color force (gluons)

Fermions (don't share quantum numbers) make up matter and come in two sorts, each of which has six flavours

Leptons	$\frac{m}{\text{MeV}/c^2}$	q	Quarks	$\frac{m}{\text{MeV}/c^2}$	q
ν_e electron neutrino	$< 2 \cdot 10^{-5}$	0	u up	5*	+2/3
e electron	0.51	-1	d down	7*	-1/3
ν_μ muon neutrino	$< .25$	0	c charm	1300*	+2/3
μ muon	106	-1	s strange	150*	-1/3
ν_τ tau neutrino	< 40	0	t top	175,000	+2/3
τ tau	1784	-1	b bottom	4800*	-1/3



Helium - not to scale, and misleading about positions

Bosons (can share quantum numbers) transmit force

Electroweak			Strong		
γ photon	0	0	g gluon	0	0
W^-	80.4	-1			
(W^+)	80.4	+1)			
Z^0	91.16	0			

* + ~300 MeV "fur coat" of virtual gluons

Fundamental forces

Grand unified theories

	Gravity	Electroweak		Strong	
		weak	EM	fundamental	residual
acts on	mass; energy	flavour	electric charge	color charge	residual
'felt' by	all	quarks, leptons	elec. charged	quarks, gluons	hadrons
trans. by	graviton (?)	$W^+ W^- Z^0$	γ	gluons	mesons
F/F_{elec}					
u-u at 10^{-18} m	10^{-41}	0.8	1	25	NA
u-u at $3 \cdot 10^{-17}$ m	10^{-41}	10^{-4}	1	60	NA
n-n in nucleus	10^{-36}	10^{-7}	1	NA	20