

# An Overview of the Standard Model

mass →	$\approx 2.3 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 173.07 \text{ GeV}/c^2$	0	$\approx 126 \text{ GeV}/c^2$
charge →	$2/3$	$2/3$	$2/3$	0	0
spin →	$1/2$	$1/2$	$1/2$	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> Higgs boson
<b>QUARKS</b>	$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
	$-1/3$	$-1/3$	$-1/3$	0	
	$1/2$	$1/2$	$1/2$	1	
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\gamma</math></b> photon	
	$0.511 \text{ MeV}/c^2$	$105.7 \text{ MeV}/c^2$	$1.777 \text{ GeV}/c^2$	$91.2 \text{ GeV}/c^2$	
	-1	-1	-1	0	
	$1/2$	$1/2$	$1/2$	1	
	<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b>Z</b> Z boson	
<b>LEPTONS</b>	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$80.4 \text{ GeV}/c^2$	
	0	0	0	$\pm 1$	
	$1/2$	$1/2$	$1/2$	1	
	<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b>W</b> W boson	
				<b>GAUGE BOSONS</b>	

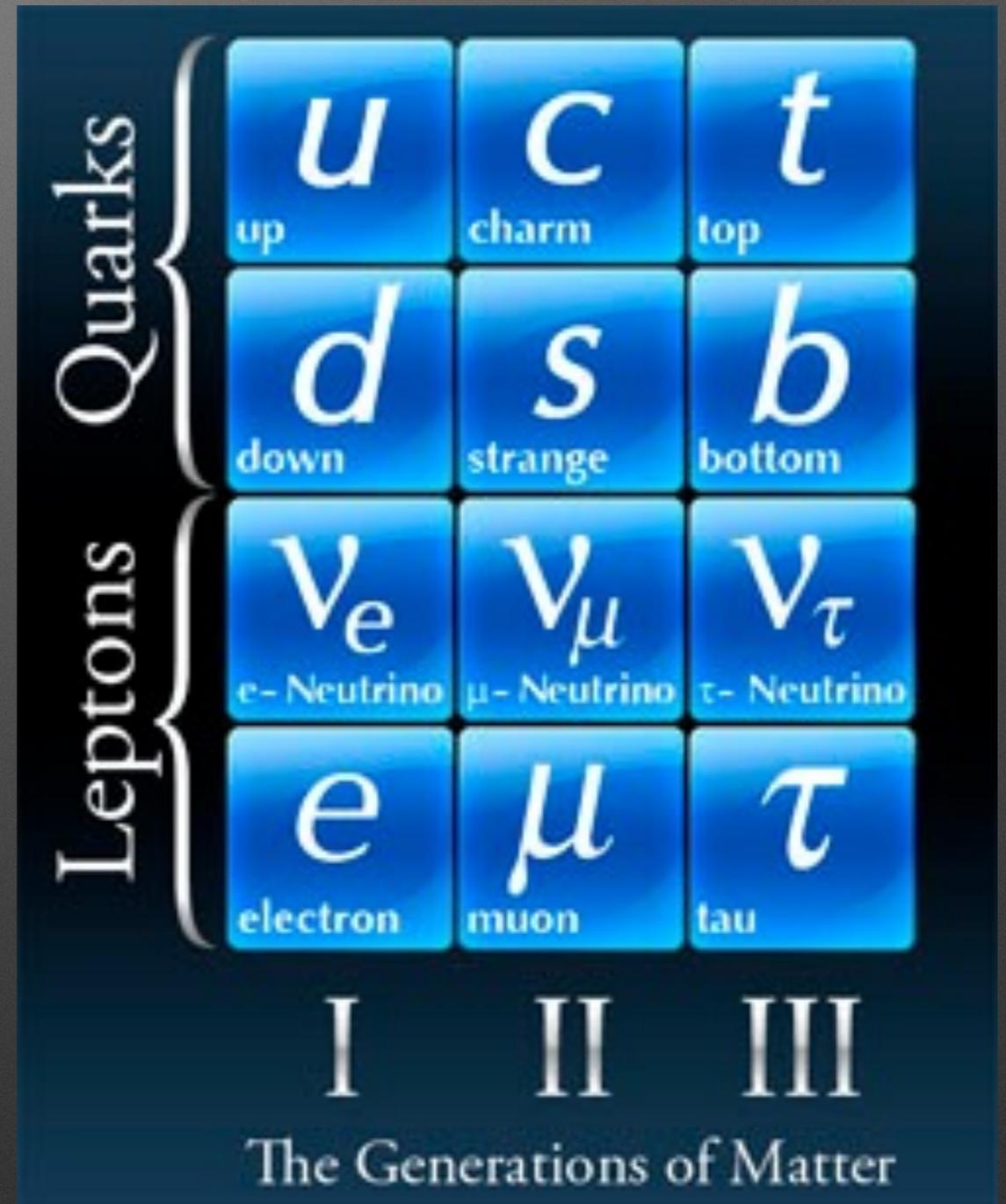
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# What is the Standard Model?

- Describes interactions of sub-atomic particles
- Mass, Charge, Spin
- As fundamental as is known
- Quarks, Leptons, Gauge Bosons
- Three Generations

# Generations of Matter

- Matter comes in 3 sets of 2
- Each set more massive
- Less massive is more stable
- Decay to smaller particles



# Forces and Force Carriers

- Three (Four) Forces- 5 (known) Force Carriers
  - Electroweak-Photon,  $W_{\pm}$  and Z bosons
  - Strong-Gluons
  - Gravity- Graviton

	mass	charge	spin																									
QUARKS	$\approx 2.3 \text{ MeV}/c^2$	$2/3$	$1/2$	<b>u</b>	up	$\approx 1.275 \text{ GeV}/c^2$	$2/3$	$1/2$	<b>c</b>	charm	$\approx 173.07 \text{ GeV}/c^2$	$2/3$	$1/2$	<b>t</b>	top	0	0	1	<b>g</b>	gluon	$\approx 126 \text{ GeV}/c^2$	0	0	0	<b>H</b>	Higgs boson		
	$\approx 4.8 \text{ MeV}/c^2$	$-1/3$	$1/2$	<b>d</b>	down	$\approx 95 \text{ MeV}/c^2$	$-1/3$	$1/2$	<b>s</b>	strange	$\approx 4.18 \text{ GeV}/c^2$	$-1/3$	$1/2$	<b>b</b>	bottom	0	0	1	<b><math>\gamma</math></b>	photon								
	$0.511 \text{ MeV}/c^2$	-1	$1/2$	<b>e</b>	electron	$105.7 \text{ MeV}/c^2$	-1	$1/2$	<b><math>\mu</math></b>	muon	$1.777 \text{ GeV}/c^2$	-1	$1/2$	<b><math>\tau</math></b>	tau	0	0	1	<b>Z</b>	Z boson	$91.2 \text{ GeV}/c^2$							
	$< 2.2 \text{ eV}/c^2$	0	$1/2$	<b><math>\nu_e</math></b>	electron neutrino	$< 0.17 \text{ MeV}/c^2$	0	$1/2$	<b><math>\nu_{\mu}</math></b>	muon neutrino	$< 15.5 \text{ MeV}/c^2$	0	$1/2$	<b><math>\nu_{\tau}</math></b>	tau neutrino	$\pm 1$	$\pm 1$	1	<b>W</b>	W boson	$80.4 \text{ GeV}/c^2$							
	LEPTONS																											

# Electroweak Force

- Combination of electromagnetic and weak forces
  - Apparent at high energies
- Weak
  - Acts through release and absorption of  $W_{\pm}$  and  $Z$  bosons
  - Only path for quarks to change "flavor"
  - Interacts with all half integer spin particles (Fermions)

# Electroweak Part II

- Electromagnetic Force
  - Interacts through release and absorption of photons
  - Charged particles interact

# Leptons

- Come in two classes
  - Charged
  - Neutral (Neutrinos)
- Half Integer Spin
- Mass
- Lepton Number

LEPTONS		
$e^-$	$\mu^-$	$\tau^-$
$\nu_e$	$\nu_\mu$	$\nu_\tau$

ANTILEPTONS		
$e^+$	$\mu^+$	$\tau^+$
$\bar{\nu}_e$	$\bar{\nu}_\mu$	$\bar{\nu}_\tau$

# Strong Force

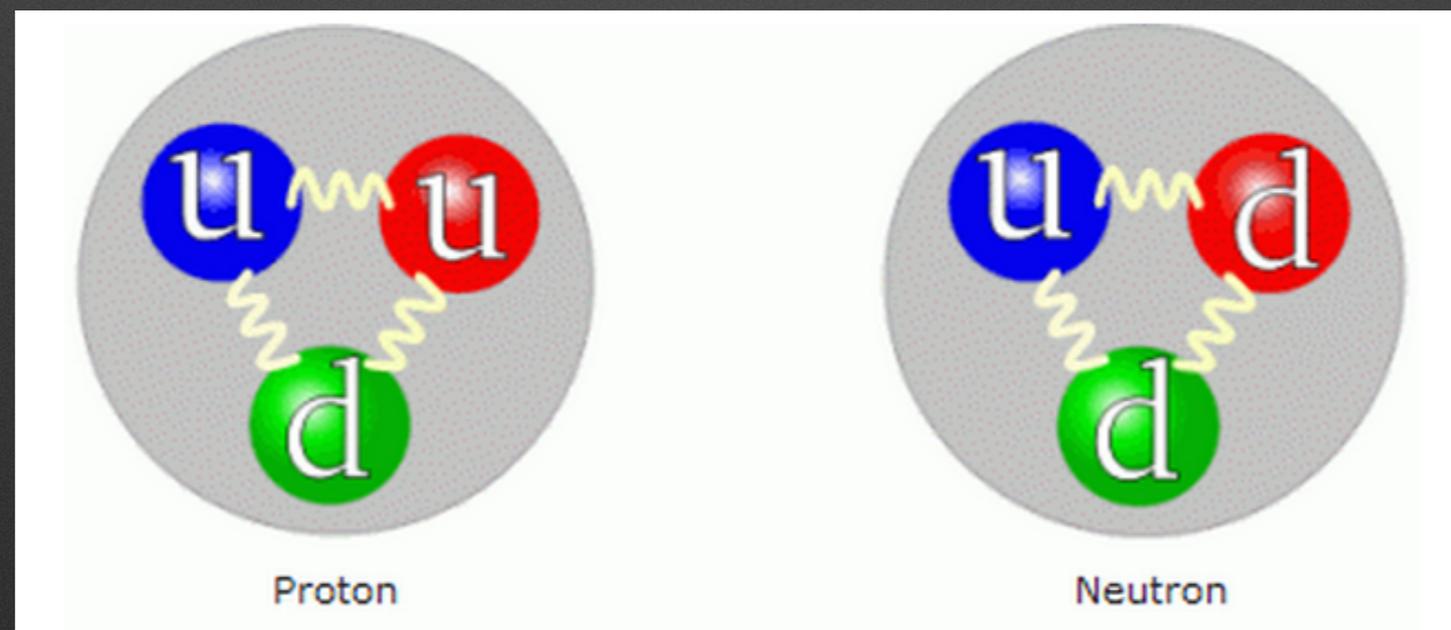
- Interacts through exchange of gluons
  - Gluons have both a color and an anticolor
- Interacts with colored particles only
- Binds quarks together
- Strongest force
  - Screened at distances

# Quarks

- Make up hadronic matter
- Interact with the strong force through gluons
- "Flavors"
- Have color charge
- Electric charge in thirds
- Color confined

# Color

- Quarks come in 6 different "colors"
  - Red Blue Green and Anti - Red, Blue and Green
- Multiquark states must neutralize color
  - i.e Red + Blue + Green or Red + Anti-Red etc.



# Questions?