

# Standard Model of Particle Physics

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# Standard Model of Particle Physics

three generations of matter (fermions)			interactions / forces (bosons)	
I	II	III		
mass charge spin $\approx 2.2 \text{ MeV}$ $+\frac{2}{3}$ $\frac{1}{2}$ <b>u</b> up	$\approx 1.3 \text{ GeV}$ $+\frac{2}{3}$ $\frac{1}{2}$ <b>c</b> charm	$\approx 173 \text{ GeV}$ $+\frac{2}{3}$ $\frac{1}{2}$ <b>t</b> top	$0$ $0$ $1$ <b>g</b> gluon	$\approx 125 \text{ GeV}$ $0$ $0$ <b>H</b> Higgs
$\approx 4.7 \text{ MeV}$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>d</b> down	$\approx 96 \text{ MeV}$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>s</b> strange	$\approx 4.2 \text{ GeV}$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>b</b> bottom	$0$ $0$ $1$ $\gamma$ photon	
$\approx 0.511 \text{ MeV}$ $-1$ $\frac{1}{2}$ <b>e</b> electron	$\approx 106 \text{ MeV}$ $-1$ $\frac{1}{2}$ $\mu$ muon	$\approx 1.777 \text{ GeV}$ $-1$ $\frac{1}{2}$ $\tau$ tau	$\approx 80.4 \text{ GeV}$ $\pm 1$ $1$ <b>W</b> W boson	
$< 1.0 \text{ eV}$ $0$ $\frac{1}{2}$ $\nu_e$ electron neutrino	$< 0.17 \text{ eV}$ $0$ $\frac{1}{2}$ $\nu_\mu$ muon neutrino	$< 18.2 \text{ MeV}$ $0$ $\frac{1}{2}$ $\nu_\tau$ tau neutrino	$\approx 91.2 \text{ GeV}$ $0$ $1$ <b>Z</b> Z boson	

QUARKS

LEPTONS

GAUGE BOSONS  
VECTOR BOSONS

SCALAR BOSONS

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	$\approx 4.7 \text{ MeV}$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>d</b> down	$\approx 96 \text{ MeV}$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>s</b> strange	$\approx 4.2 \text{ GeV}$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>b</b> bottom	$0$ $0$ $1$ $\gamma$ photon
LEPTONS	$\approx 0.511 \text{ MeV}$ $-1$ $\frac{1}{2}$ <b>e</b> electron	$\approx 106 \text{ MeV}$ $-1$ $\frac{1}{2}$ <b><math>\mu</math></b> muon	$\approx 1.777 \text{ GeV}$ $-1$ $\frac{1}{2}$ <b><math>\tau</math></b> tau	$\approx 80.4 \text{ GeV}$ $\pm 1$ $1$ <b>W</b> W boson
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				SCALAR BOSONS $\approx 125 \text{ GeV}$ $0$ <b>H</b> Higgs

- **Fermions** of spin  $1/2$ , which make up matter



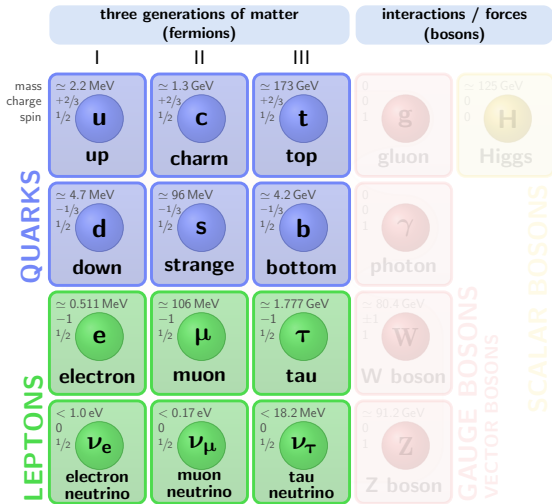
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$\approx 4.7 \text{ MeV}$ $-1/3$ $1/2$ <b>d</b> down	$\approx 96 \text{ MeV}$ $-1/3$ $1/2$ <b>s</b> strange	$\approx 4.2 \text{ GeV}$ $-1/3$ $1/2$ <b>b</b> bottom	$0$ $0$ $1$ $\gamma$ photon	
$\approx 0.511 \text{ MeV}$ $-1$ $1/2$ <b>e</b> electron	$\approx 106 \text{ MeV}$ $-1$ $1/2$ <b><math>\mu</math></b> muon	$\approx 1.777 \text{ GeV}$ $-1$ $1/2$ <b><math>\tau</math></b> tau	$\approx 80.4 \text{ GeV}$ $\pm 1$ $1$ <b>W</b> W boson	
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- Quarks
- Leptons

# Standard Model of Particle Physics



- ▶ **Fermions** of spin  $1/2$ , which make up matter
  - ▶ Quarks
  - ▶ Leptons
  - ▶ Three generations

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three generations of matter (fermions)							interactions / forces (bosons)				
							I	II	III		
mass charge spin	$\simeq 2.2 \text{ MeV}$ $+2/3$ $1/2$	<b>u</b> up	$\simeq 1.3 \text{ GeV}$ $+2/3$ $1/2$	<b>c</b> charm	$\simeq 173 \text{ GeV}$ $+2/3$ $1/2$	<b>t</b> top	0 0 1	<b>g</b> gluon	$\simeq 125 \text{ GeV}$ 0 0	<b>H</b> Higgs	
	$\simeq 4.7 \text{ MeV}$ $-1/3$ $1/2$	<b>d</b> down	$\simeq 96 \text{ MeV}$ $-1/3$ $1/2$	<b>s</b> strange	$\simeq 4.2 \text{ GeV}$ $-1/3$ $1/2$	<b>b</b> bottom	0 0 1	$\gamma$ photon			
	$\simeq 0.511 \text{ MeV}$ -1 $1/2$	<b>e</b> electron	$\simeq 106 \text{ MeV}$ -1 $1/2$	$\mu$ muon	$\simeq 1.777 \text{ GeV}$ -1 $1/2$	$\tau$ tau	$\simeq 80.4 \text{ GeV}$ $\pm 1$ 1	<b>W</b> W boson			
LEPTONS	$< 1.0 \text{ eV}$ 0 $1/2$	$\nu_e$ electron neutrino	$< 0.17 \text{ eV}$ 0 $1/2$	$\nu_\mu$ muon neutrino	$< 18.2 \text{ MeV}$ 0 $1/2$	$\nu_\tau$ tau neutrino	$\simeq 91.2 \text{ GeV}$ 0 1	<b>Z</b> Z boson			

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three generations of matter (fermions)			interactions / forces (bosons)	
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QUARKS	I	II	III	
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LEPTONS	mass $\approx 0.511 \text{ MeV}$ charge $-1$ spin $1/2$ <b>e</b> electron	mass $\approx 106 \text{ MeV}$ charge $-1$ spin $1/2$ <b><math>\mu</math></b> muon	mass $\approx 1.777 \text{ GeV}$ charge $-1$ spin $1/2$ <b><math>\tau</math></b> tau	mass $0$ charge $0$ spin $1$ <b><math>\gamma</math></b> photon
	mass $< 1.0 \text{ eV}$ charge $0$ spin $1/2$ <b><math>\nu_e</math></b> electron neutrino	mass $< 0.17 \text{ eV}$ charge $0$ spin $1/2$ <b><math>\nu_\mu</math></b> muon neutrino	mass $< 18.2 \text{ MeV}$ charge $0$ spin $1/2$ <b><math>\nu_\tau</math></b> tau neutrino	mass $\approx 80.4 \text{ GeV}$ charge $\pm 1$ spin $1$ <b>W</b> W boson
				mass $\approx 91.2 \text{ GeV}$ charge $0$ spin $1$ <b>Z</b> Z boson

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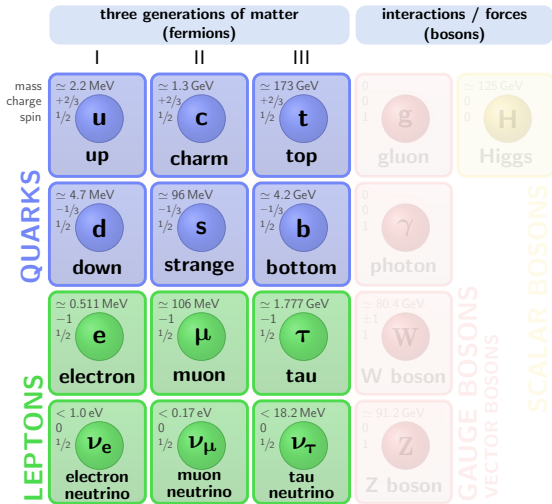
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LEPTONS	$\approx 0.511 \text{ MeV}$ $-1$ $\frac{1}{2}$ <b>e</b> electron	$\approx 106 \text{ MeV}$ $-1$ $\frac{1}{2}$ $\mu$ muon	$\approx 1.777 \text{ GeV}$ $-1$ $\frac{1}{2}$ $\tau$ tau	$\approx 80.4 \text{ GeV}$ $\pm 1$ $1$ <b>W</b> W boson
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				GAUGE BOSONS VECTOR BOSONS
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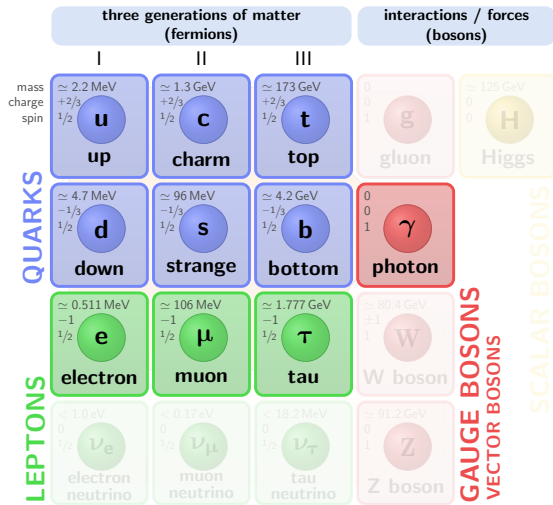
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QUARKS	mass charge spin	<div> <math>\approx 2.2 \text{ MeV}</math>  <math>+2/3</math>  <math>1/2</math>  <b>u</b>                      up                 </div>	<div> <math>\approx 1.3 \text{ GeV}</math>  <math>+2/3</math>  <math>1/2</math>  <b>c</b>                      charm                 </div>	<div> <math>\approx 173 \text{ GeV}</math>  <math>+2/3</math>  <math>1/2</math>  <b>t</b>                      top                 </div>
		<div> <math>\approx 4.7 \text{ MeV}</math>  <math>-1/3</math>  <math>1/2</math>  <b>d</b>                      down                 </div>	<div> <math>\approx 96 \text{ MeV}</math>  <math>-1/3</math>  <math>1/2</math>  <b>s</b>                      strange                 </div>	<div> <math>\approx 4.2 \text{ GeV}</math>  <math>-1/3</math>  <math>1/2</math>  <b>b</b>                      bottom                 </div>
		<div> <math>\approx 0.511 \text{ MeV}</math>  <math>-1</math>  <math>1/2</math>  <b>e</b>                      electron                 </div>	<div> <math>\approx 106 \text{ MeV}</math>  <math>-1</math>  <math>1/2</math>  <b><math>\mu</math></b>                      muon                 </div>	<div> <math>\approx 1.777 \text{ GeV}</math>  <math>-1</math>  <math>1/2</math>  <b><math>\tau</math></b>                      tau                 </div>
LEPTONS		<div> <math>&lt; 1.0 \text{ eV}</math>  <math>0</math>  <math>1/2</math>  <b><math>\nu_e</math></b>                      electron neutrino                 </div>	<div> <math>&lt; 0.17 \text{ eV}</math>  <math>0</math>  <math>1/2</math>  <b><math>\nu_\mu</math></b>                      muon neutrino                 </div>	<div> <math>&lt; 18.2 \text{ MeV}</math>  <math>0</math>  <math>1/2</math>  <b><math>\nu_\tau</math></b>                      tau neutrino                 </div>
			III	
			<div> <math>0</math>  <math>0</math>  <math>1</math>  <b>g</b>                      gluon                 </div>	<div> <math>\approx 125 \text{ GeV}</math>  <math>0</math>  <math>0</math>  <b>H</b>                      Higgs                 </div>
			<div> <math>0</math>  <math>0</math>  <math>1</math>  <b><math>\gamma</math></b>                      photon                 </div>	
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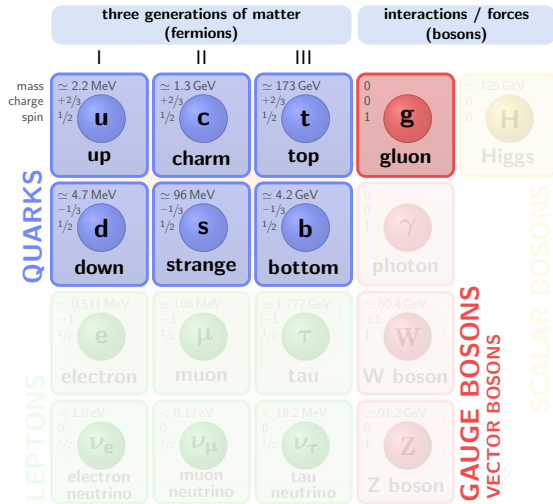
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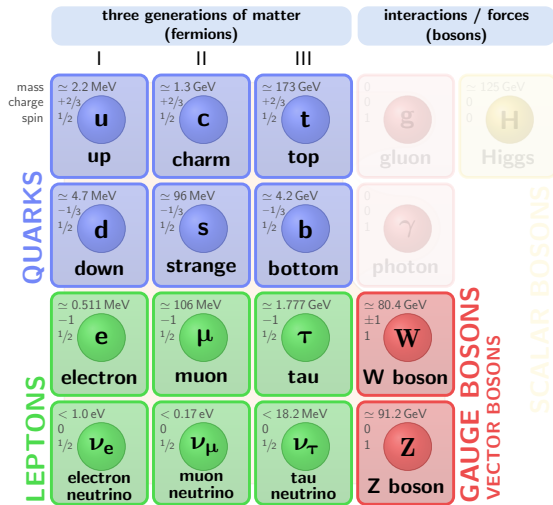
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  - ▶ Electromagnetic interaction

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  - ▶ Strong interaction

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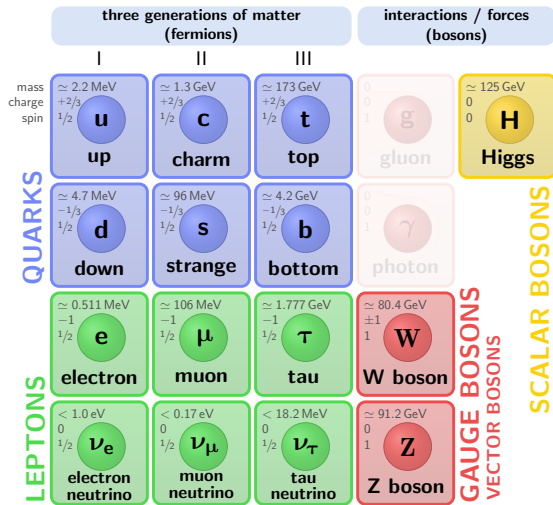
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- ▶ One **scalar boson** of spin  $0$ , which gives mass to fermions and weak bosons

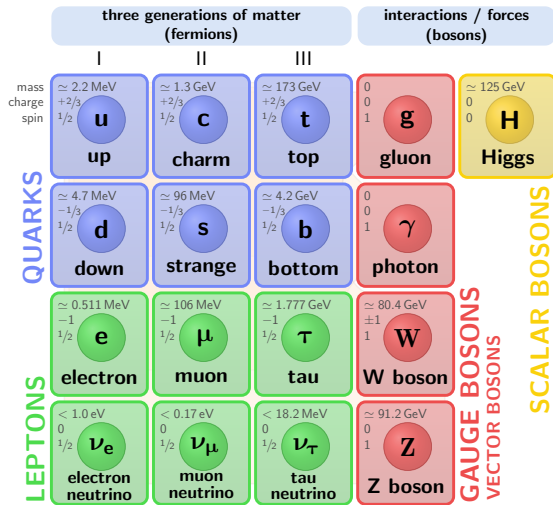
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