

# Feynman Diagrams & the Higgs Boson

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IB PHYSICS | ATOMIC PHYSICS




















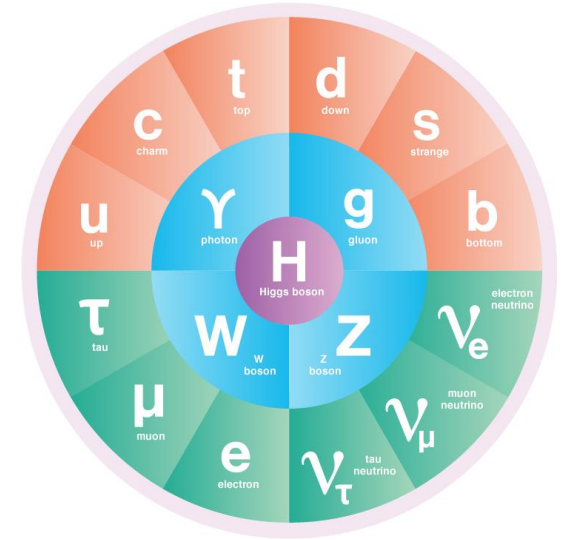
# IB Physics Data Booklet

Sub-topic 7.1 – Discrete energy and radioactivity		Sub-topic 7.2 – Nuclear reactions																												
$E = hf$ $\lambda = \frac{hc}{E}$		$\Delta E = \Delta m c^2$																												
Sub-topic 7.3 – The structure of matter																														
<table border="1"> <thead> <tr> <th>Charge</th> <th colspan="3">Quarks</th> <th>Baryon number</th> </tr> </thead> <tbody> <tr> <td><math>\frac{2}{3}e</math></td> <td>u</td> <td>c</td> <td>t</td> <td><math>\frac{1}{3}</math></td> </tr> <tr> <td><math>\frac{1}{3}e</math></td> <td>d</td> <td>s</td> <td>b</td> <td><math>\frac{1}{3}</math></td> </tr> </tbody> </table> <p>All quarks have a strangeness number of 0 except the strange quark that has a strangeness number of -1</p>		Charge	Quarks			Baryon number	$\frac{2}{3}e$	u	c	t	$\frac{1}{3}$	$\frac{1}{3}e$	d	s	b	$\frac{1}{3}$	<table border="1"> <thead> <tr> <th>Charge</th> <th colspan="3">Leptons</th> </tr> </thead> <tbody> <tr> <td>-1</td> <td>e</td> <td><math>\mu</math></td> <td><math>\tau</math></td> </tr> <tr> <td>0</td> <td><math>\nu_e</math></td> <td><math>\nu_\mu</math></td> <td><math>\nu_\tau</math></td> </tr> </tbody> </table> <p>All leptons have a lepton number of 1 and antileptons have a lepton number of -1</p>		Charge	Leptons			-1	e	$\mu$	$\tau$	0	$\nu_e$	$\nu_\mu$	$\nu_\tau$
Charge	Quarks			Baryon number																										
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0	$\nu_e$	$\nu_\mu$	$\nu_\tau$																											
	Gravitational	Weak	Electromagnetic	Strong																										
Particles experiencing	All	Quarks, leptons	Charged	Quarks, gluons																										
Particles mediating	Graviton	$W^+, W^-, Z^0$	$\gamma$	Gluons																										

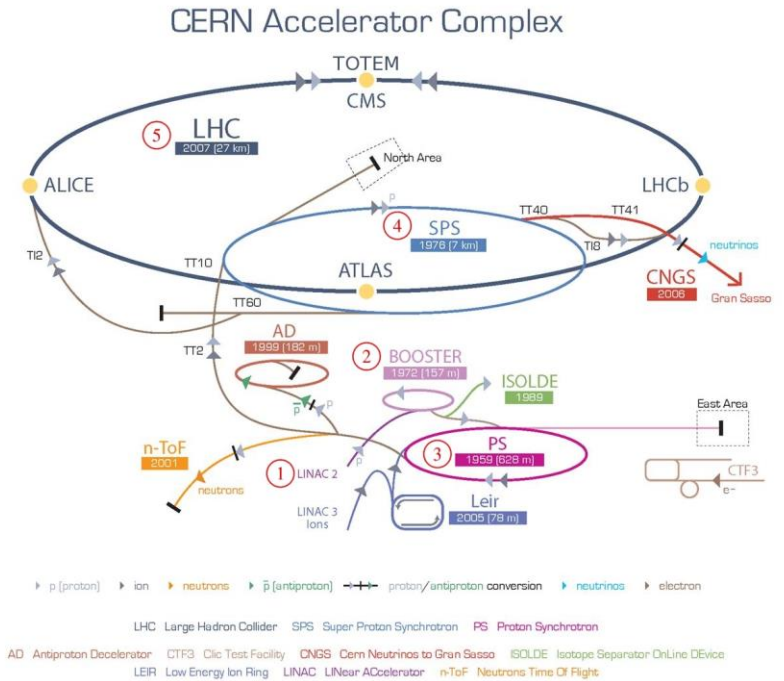
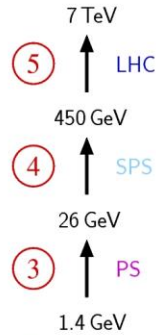
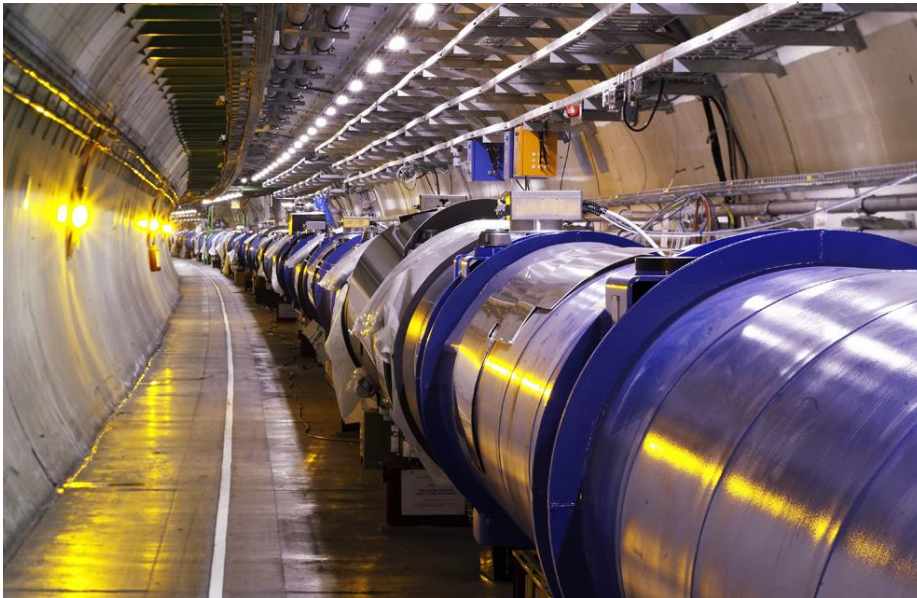
# The Standard Model

## Standard Model of Elementary Particles

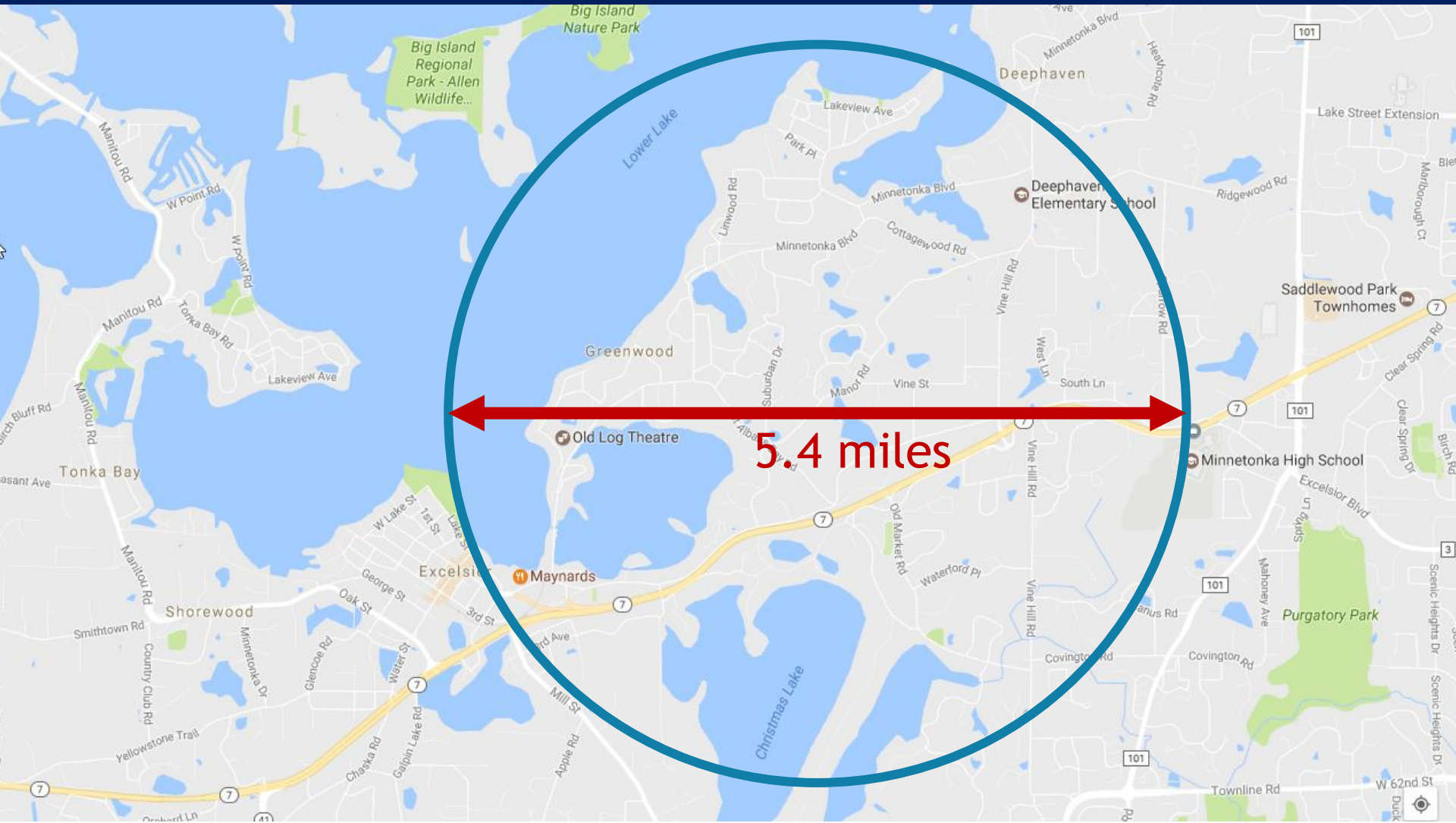
	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
mass	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	0	$\approx 124.97 \text{ GeV}/c^2$
charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0	0
spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
QUARKS	$\frac{2}{3}$ $\frac{1}{2}$  u up	$\frac{2}{3}$ $\frac{1}{2}$  c charm	$\frac{2}{3}$ $\frac{1}{2}$  t top	 g gluon	 H higgs
	$-\frac{1}{3}$ $\frac{1}{2}$  d down	$-\frac{1}{3}$ $\frac{1}{2}$  s strange	$-\frac{1}{3}$ $\frac{1}{2}$  b bottom	 $\gamma$ photon	
	$-1$ $\frac{1}{2}$  e electron	$-1$ $\frac{1}{2}$  $\mu$ muon	$-1$ $\frac{1}{2}$  $\tau$ tau	 Z Z boson	
LEPTONS	$< 1.0 \text{ eV}/c^2$ $0$ $\frac{1}{2}$  $\nu_e$ electron neutrino	$< 0.17 \text{ MeV}/c^2$ $0$ $\frac{1}{2}$  $\nu_\mu$ muon neutrino	$< 18.2 \text{ MeV}/c^2$ $0$ $\frac{1}{2}$  $\nu_\tau$ tau neutrino	 W W boson	
				GAUGE BOSONS VECTOR BOSONS	SCALAR BOSONS



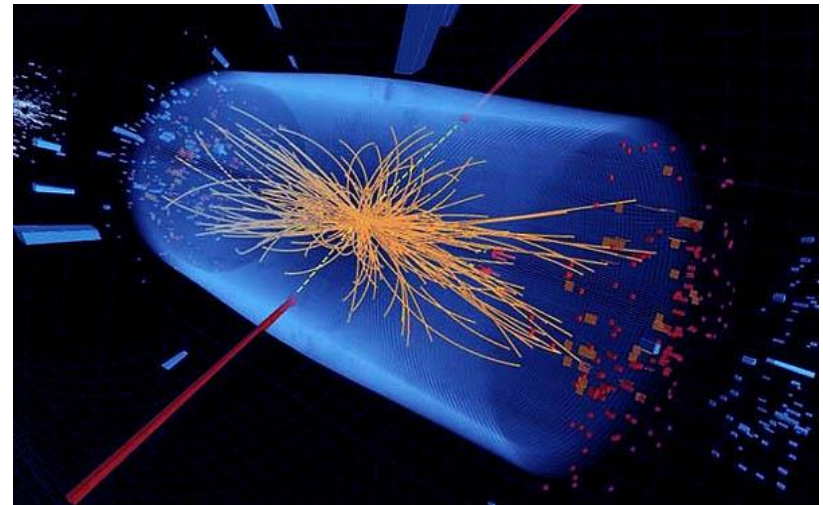
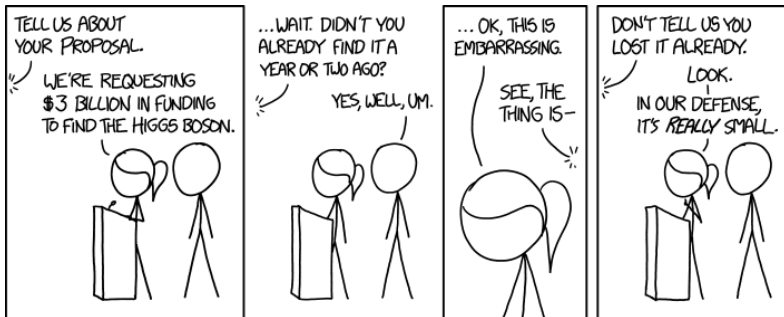
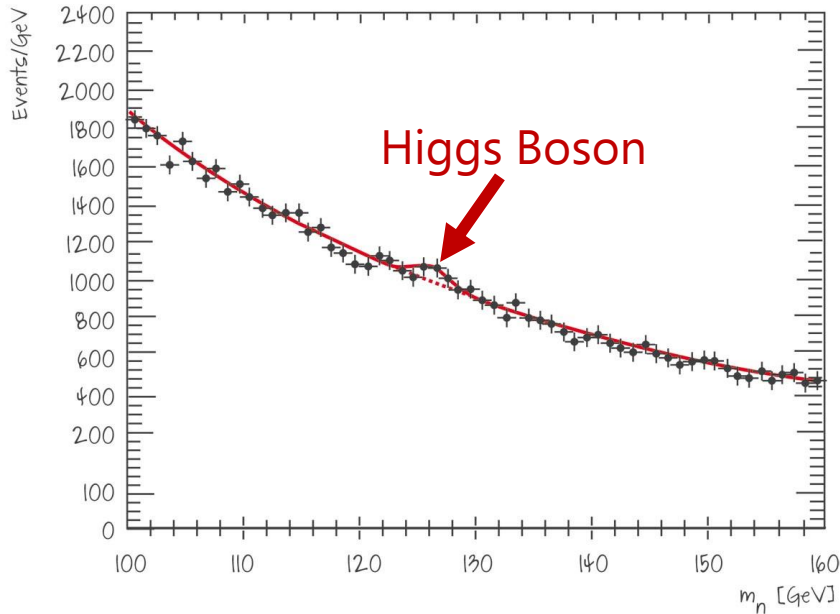
# The Large Hadron Collider



# The Large Hadron Collider

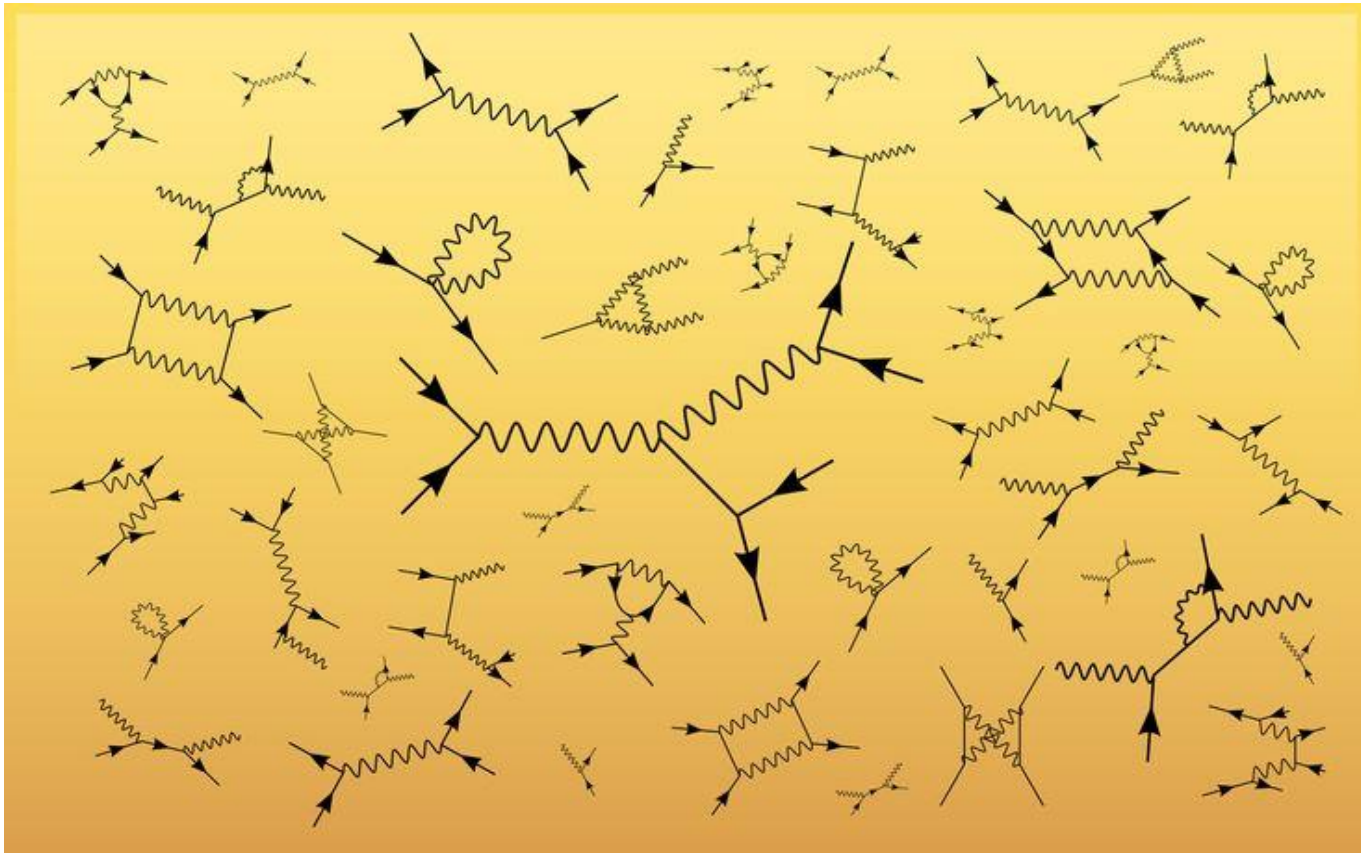


# The Higgs Boson



# Feynman Diagrams

Useful to represent, analyze, and predict particle interactions



# Feynman Diagrams are like Comics



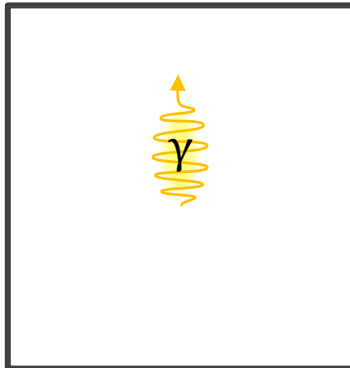
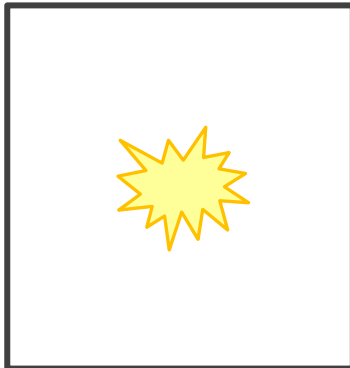
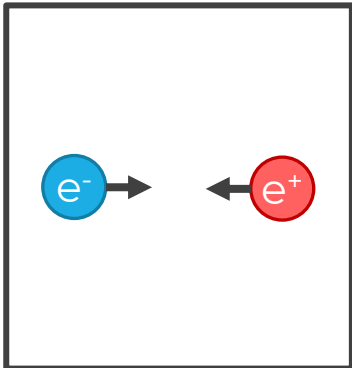
**Set Up**



**Event**



**Result**

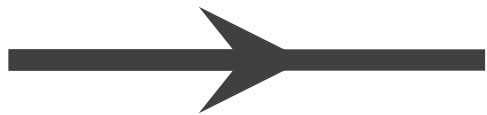


An electron and positron (antielectron) annihilate into a photon

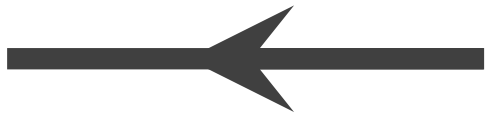


# “The Characters”

Matter Particle



Antimatter Particle



0  
0  
1

**$\gamma$**

photon



0  
0  
1

**g**

gluon



90.2 GeV

0  
1

**$Z^0$**

weak force



80.4 GeV

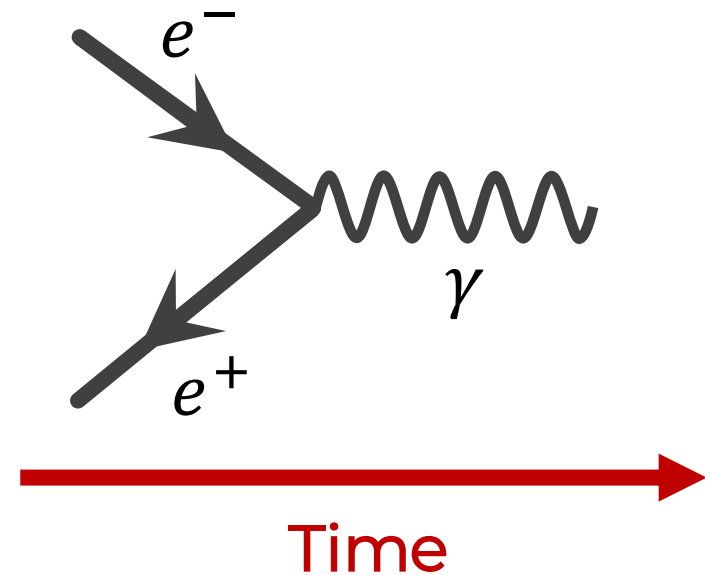
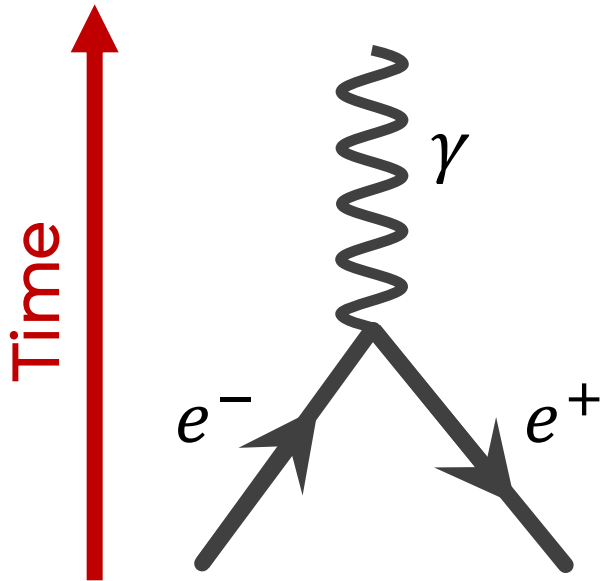
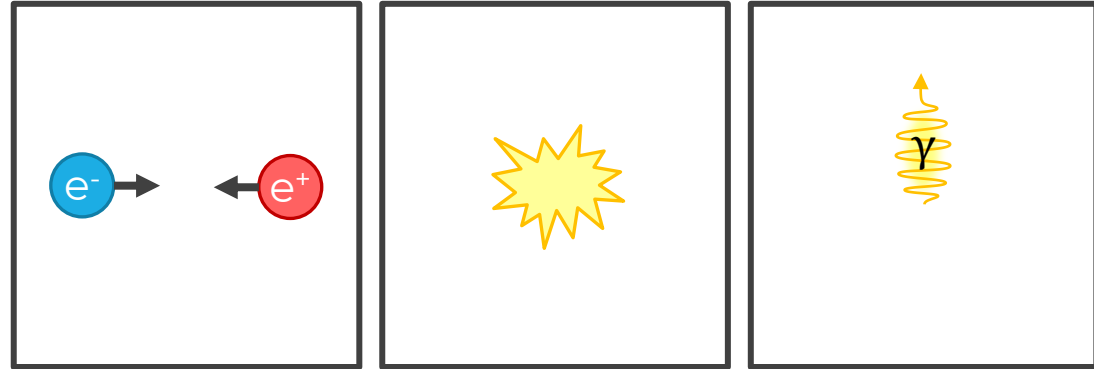
$\pm 1$   
1

**$W^\pm$**

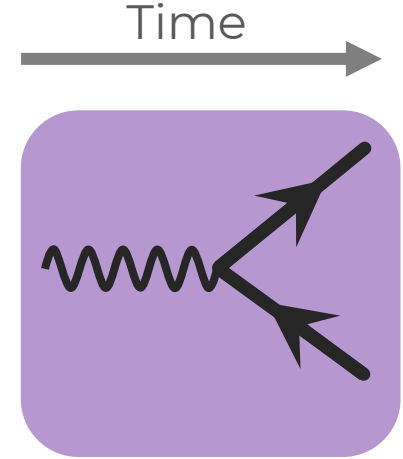
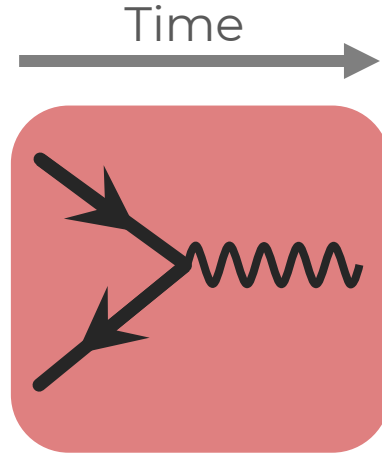
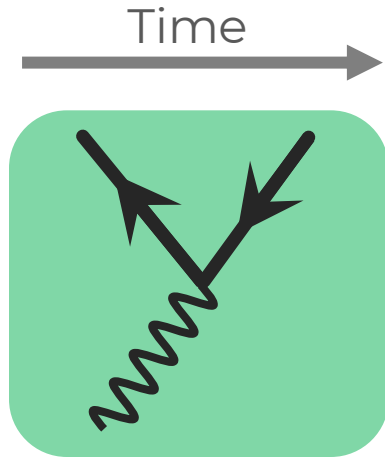
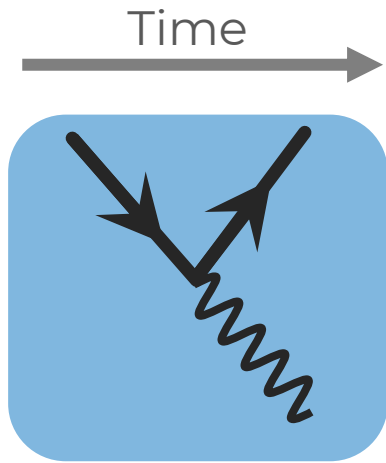
weak force

# Representing Time

An electron and positron (antielectron) annihilate into a photon



# Match these!



a photon spontaneously  
“pair produces” an  
electron and positron

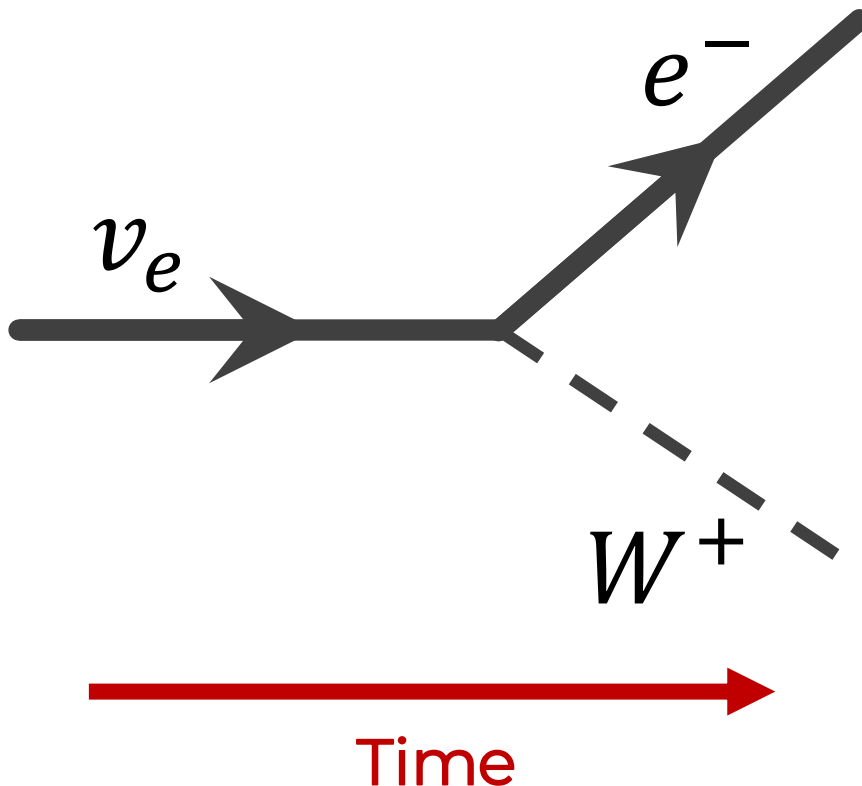
a positron absorbs a  
photon and keeps going

an electron emits a  
photon and keeps going

an electron and  
positron annihilate  
into a photon

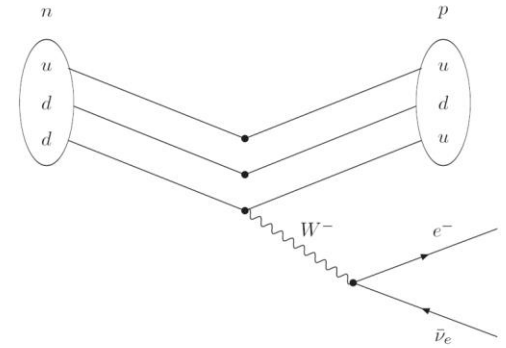
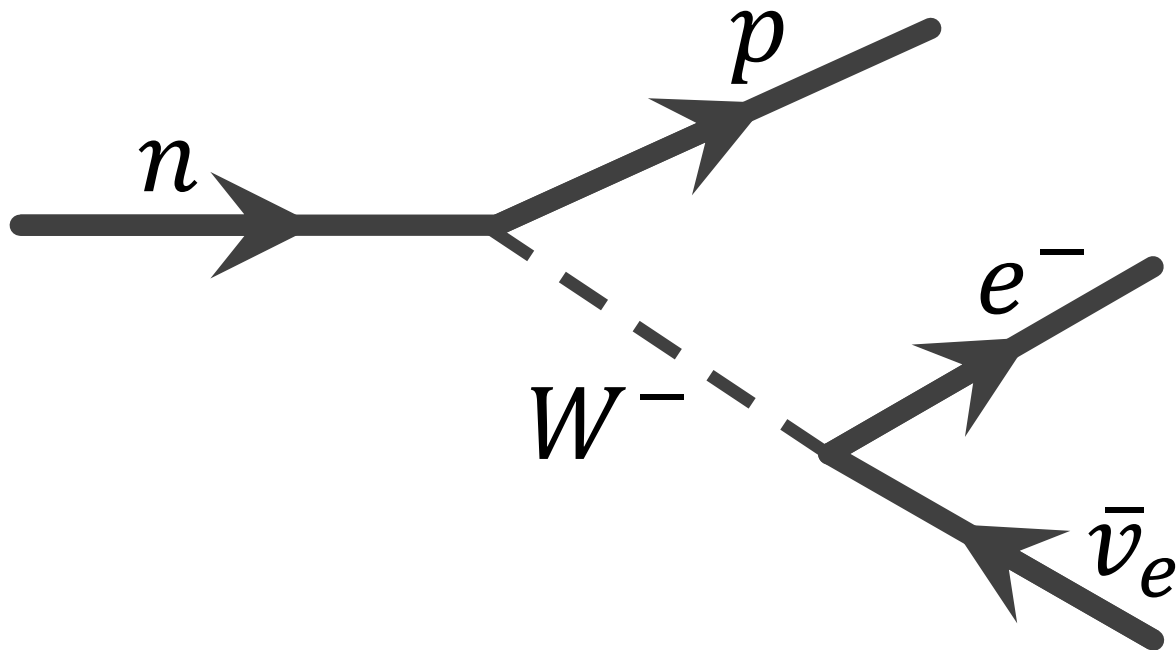
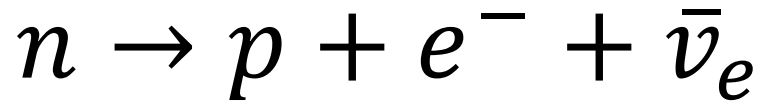
# Junction Conservation

Every junction will have two lines with arrows (one pointing in, one pointing out) meeting a single exchange particle and all properties are conserved before/after

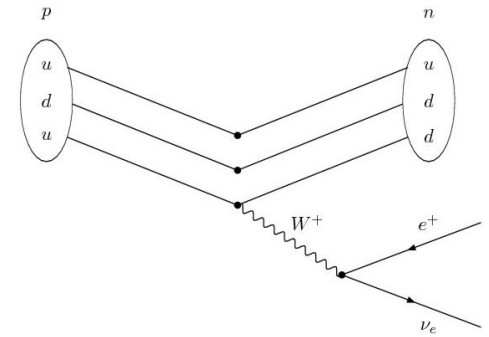
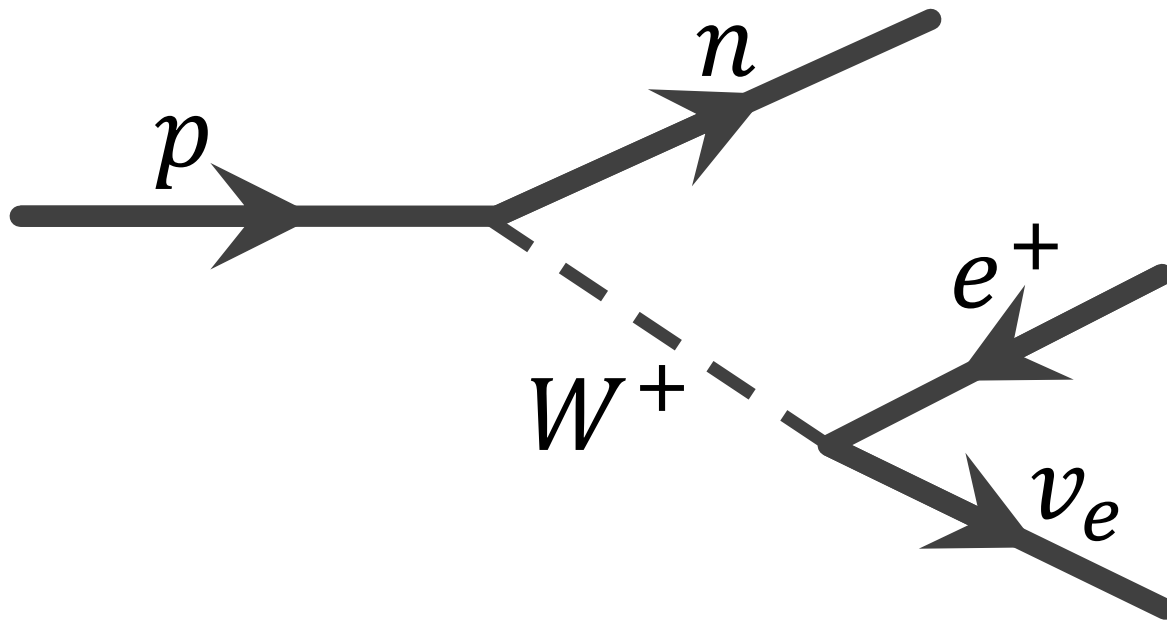
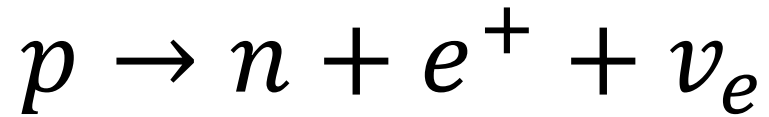


	$\nu_e$	$e^-$	$W^+$
Baryon #	0	0	0
Lepton #	1	1	0
Charge	0	-1	+1

# Beta-Negative Decay



# Beta-Positive Decay



Time

