


The Standard Model


In cupcakes!



Let's eat our
way through
this topic!

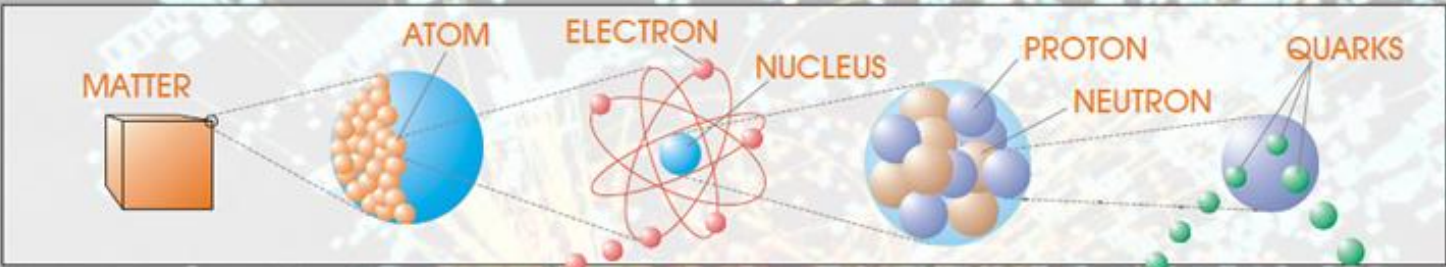
- Thanks to Sally Weatherly for the original cupcake idea!

The standard model represents our best understanding of the fundamental nature of matter. It proposes 12 fundamental matter particles, fermions, organised in three generations. The first generation includes the electron, the neutrino and the two quarks that make up protons and neutrons, i.e. the normal matter of our universe. The other generations are only found in high-energy collisions in particle accelerators or in naturally occurring cosmic rays. Each has a charge of a fraction of the charge on an electron ($1.60 \times 10^{-19} \text{ C}$).



The Structure of Matter

Particle Physics 2



LEPTONS	
These particles exist on their own	
Charge = -1	Charge = 0
<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> 1st Family ELECTRON (e^-) Responsible for electricity and chemical reactions. Mass = $0.51 \text{ MeV}/c^2$ </div> </div>	<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> ELECTRON NEUTRINO (ν_e) Rarely interacts with other matter. Observed 1956. </div> </div>
<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> 2nd Family MUON (μ^-) A heavier relative of the electron. Discovered 1937. Mass = $0.106 \text{ GeV}/c^2$ </div> </div>	<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> MUON NEUTRINO (ν_μ) A relative of ν_e. Discovered 1962. </div> </div>
<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> 3rd Family TAU (τ^-) A heavier relative of the electron and muon. Discovered 1975. Mass = $1.78 \text{ GeV}/c^2$ </div> </div>	<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> TAU NEUTRINO (ν_τ) Indirect evidence 1975. Directly observed 2000. </div> </div>

QUARKS	
These particles only exist bound together	
Charge = +2/3	Charge = -1/3
<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> UP (u) Mass $\sim 3 \text{ MeV}/c^2$ </div> </div>	<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> DOWN (d) Mass $\sim 6 \text{ MeV}/c^2$ </div> </div>
Protons are made up of two up quarks and one down quark. Neutrons are made up of one up quark and two down quarks.	
<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> CHARM (c) A heavier relative of the up quark. Discovered 1973. Mass $\sim 1.2 \text{ GeV}/c^2$ </div> </div>	<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> STRANGE (s) A heavier relative of the down quark. Evidence 1947. Mass $\sim 0.1 \text{ GeV}/c^2$ </div> </div>
<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> TOP (t) The heaviest quark. Discovered 1994. Mass $\sim 175 \text{ GeV}/c^2$ </div> </div>	<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 10px;">{</div> <div> BOTTOM (b) A heavier relative of the down and strange quarks. Discovered 1977. Mass $\sim 4.2 \text{ GeV}/c^2$ </div> </div>

Until recently it was generally thought that the neutrinos have zero mass. Several recent experiments suggest that the mass of the neutrinos is not zero.

ALL OF THE ABOVE PARTICLES HAVE AN ANTIPARTICLE COUNTERPART.

A particle and its antiparticle can annihilate to produce the bosons that carry forces, e.g. $e^+e^- \rightarrow \gamma\gamma$.

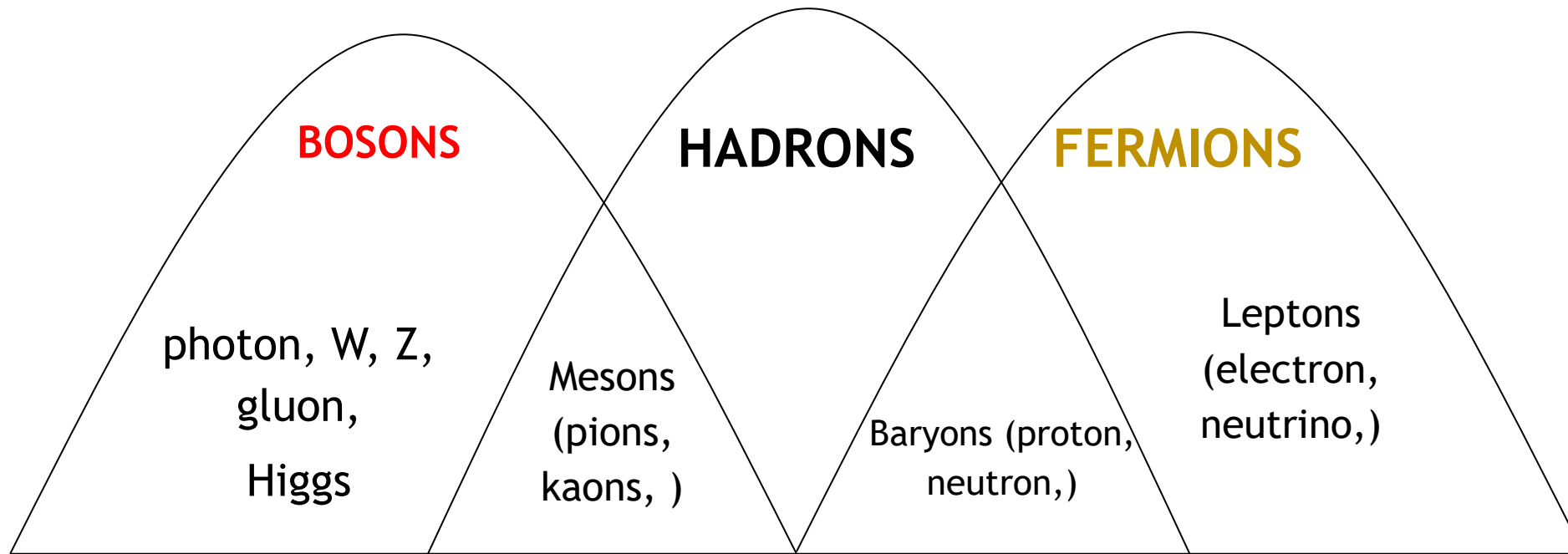
A particle - antiparticle pair can be produced from a force-carrying boson, e.g. $Z \rightarrow b\bar{b}$, $\gamma \rightarrow e^+e^-$.

Background: Simulation of a Higgs decay to two hadronic jets

Let's Tweet!
:in 140
characters or
less

#HADRON	#MUON
#BARYON	#ANNIHILATE
#MESON	#BOSON
#POSITRON	#LEPTON
#STANDARD MODEL	#4 FUNDAMENTAL FORCES
#NEUTRINO	#STRONG FORCE
#QUARK	#WEAK FORCE
#GLUON	#GRAVITATIONAL FORCE
#COLOUR	#ANTIMATTER
#SPIN	#FERMION
#EXCHANGE PARTICLE	
#ELECTROMAGNETIC FORCE	

Classification of particles



For example, a proton is both a fermion (a matter particle) and a hadron (a particle made up of quarks), Bosons are called the Exchange particles.

The Particle Zoo

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

Code to our Quarks

Skittle	Colour	Corresponding Quark
	Yellow	Up
	Red	Down
	Green	Strange
	Yellow with s facing up	Anti-Up
	Red with s facing up	Anti-Down
	Green with s facing up	Anti-Strange

You will be given a cupcake and the particle you are to build

Collect the Skittles you need and build your particle. (wash hands and lift the skittles with covid safe tweezers!)

Place it on the “dining table” for us to all identify, add your name underneath but not the name of your particle

Go and identify each person’s particle and fill in the table. If you built the wrong particle I eat your cupcake!

A Delicious Way to Classify Particles

[illegible]

Mesons

Meson	Symbol	Baryon No. (B)	Charge (Q)	Strangeness (S)	Quark Structure
kay-plus	K^+	0	+1	1	$u\bar{s}$
kay-zero	K^0	0	0	1	$d\bar{s}$
kay-minus	K^-	0	-1	1	$s\bar{u}$
phi	ϕ^0	0	0	0	$s\bar{s}$
pi-plus	π^+	0	+1	0	$u\bar{d}$
pi-zero	π^0	0	0	0	$u\bar{u}$ or $d\bar{d}$
pi-minus	π^-	0	-1	0	$d\bar{u}$

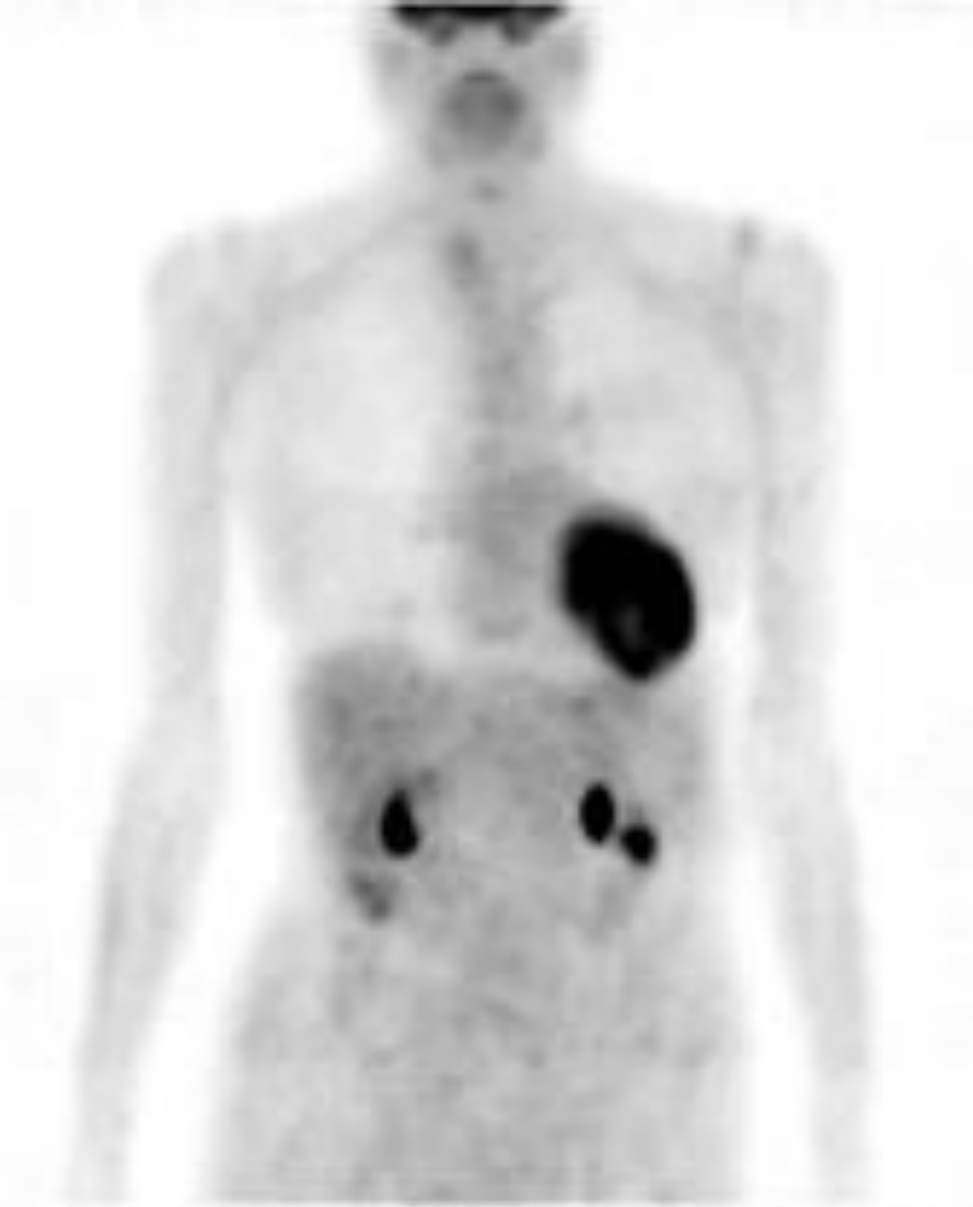
Each meson has a corresponding anti-meson, with opposite charge and quark structure.



Baryons

Baryon	Symbol	Baryon No. (B)	Charge (Q)	Strangeness (S)	Quark Structure
neutron	n^0	1	0	0	udd
proton	p^+	1	+1	0	uud
delta-plus	Δ^+	1	+1	0	uud
delta-zero	Δ^0	1	0	0	udd
delta-minus	Δ^-	1	-1	0	ddd
lambda	Λ	1	0	-1	uds
sigma-plus	Σ^+	1	+1	-1	uus
sigma-zero	Σ^0	1	0	-1	uds
sigma-minus	Σ^-	1	-1	-1	dds

Each baryon has a corresponding anti-baryon, with opposite charge and quark structure.



PET scan of patient with lung cancer

Research Task- The PET Scanner

1. **A PET scanner works using the phenomenon of particle and anti-particle annihilation.** Produce a short presentation including the following points:
 - A labelled diagram of the PET Scanner
 - An explanation of how it works: specifically how it incorporates particle and anti-particle annihilation;
 - Why the device is useful and what is it used for;
 - A real life example of where you may find this device.
2. Choose an appropriate form of presentation to place on TEAMS eg
 - A digital presentation (e.g. Powerpoint, Keynote, Prezi, etc)
 - An information booklet
 - A mind map
 - A short video