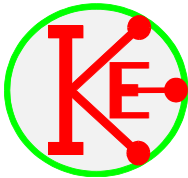


CROCHET PARTICLE ZOO



## Particle Zoo

During the first half of the 20th century, the number of 'elementary particles' continued to increase until by the late 1960s, there were well over 100. Clearly, they could not all be 'elementary'!

In 1964, two physicists, Murray Gell-Mann and George Zweig independently proposed a theory that could account for all of these 'elementary' particles, but this required the existence of three new 'fundamental particles' which he called Quarks.

Between 1967 and 1973, physicists searched experimentally for these Quarks and in 1968 the first evidence appeared when high energy electrons were fired at protons and neutrons. In both cases, the electrons appeared to be scattered by three points within the protons and neutrons.

Since then, six different types of Quark, and their antiparticles, have been experimentally discovered, though no one has managed to produce an individual Quark.

The theory has been developed into the Standard Model for matter and has been very successful in explaining all of the 'elementary' particles and their properties.

The Standard Model consists of two main types of fundamental particles, Leptons and Quarks.

Leptons are not affected by the Strong nuclear force but quarks are.

Within each of the two types of fundamental particles, there are three generations.

The first generation are the particles that are present when energy is low. These are the particles we normally experience, e.g. electrons and up and down quarks, which make up all of the matter around us.

The second generation of fundamental particles occur when the energy is much higher and can be detected from exploding stars in space. A common example is muons.

The third generation of fundamental particles only occur at the highest energy levels, those found in the largest particle accelerators and at the beginning of the universe, shortly after the 'big bang'.

Each Lepton and Quark particle also has an 'antiparticle', where the properties of the particle are reversed.

A complete list of the Standard Model particles is given on page 2.

As well as the fundamental particles, there are three other fundamental particles.

The W and the Z gauge bosons are responsible for the Weak Nuclear force, while the Higgs boson is responsible for other particles interacting with the Higgs field which causes particles to have mass.

There are two other particles involved with forces, the photon, which is responsible for the Electromagnetic force and the Gluon, which is a hypothetical, mass less particle thought to be responsible for the Strong Nuclear force, ('glues' quarks together!)

Neutrinos are interesting particles in that there is evidence that they can oscillate between generations, e.g. an muon neutrino can change into a tauon neutrino and back again.

To try to represent this, only the electron neutrino (and its anti particle) are made as complete models. The higher generations are formed by adding 'coats' to the lower generations. By adding and removing the coats, the neutrino models can be quickly changed between generations.

## Standard Model Particles

Generation	Particle	Charge (e)	Mass kg
	<b>Leptons</b>		
<b>1</b>	Electron	-1	$9.1 \times 10^{-31}$
<b>1</b>	E neutrino	0	
<b>2</b>	Muon	-1	$1.9 \times 10^{-28}$
<b>2</b>	M neutrino	0	
<b>3</b>	Tau	-1	$3.2 \times 10^{-27}$
<b>3</b>	T neutrino	0	
	<b>Quarks</b>		
<b>1</b>	Up	$+2/3$	$4.5 \times 10^{-30}$
<b>1</b>	Down	$-1/3$	$5.0 \times 10^{-30}$
<b>2</b>	Strange	$-1/3$	$1.7 \times 10^{-28}$
<b>2</b>	Charm	$+2/3$	$2.3 \times 10^{-27}$
<b>3</b>	Bottom	$-1/3$	$7.8 \times 10^{-27}$
<b>3</b>	Top	$+2/3$	$3.1 \times 10^{-25}$
	<b>Bosons</b>		
	Higgs	0	$2.2 \times 10^{-25}$
	W+	+1	$3.7 \times 10^{-27}$
	W-	-1	$3.7 \times 10^{-27}$
	Z	0	$4.4 \times 10^{-27}$
	Gluon		
	Photon		

In this representation of the Particle Zoo, Leptons are green and Quarks are brown, but there is nothing sacred about these colours, though it is worth avoiding red and black so that these can be used to show the charge when making the eyes.

First generation particles have two arms, second generation particles have four arms and third generation particles have six arms.

The charge on the particle is represented by the number of eyes, each eye representing  $1/3$  of the electron charge. Negative charge eyes are black and positive charge eyes are red.

Example, a muon would be green, with four arms and three black eyes.

It is important that children understand that the second and third generation particles are more massive than the first generation. To achieve this, weights are added to the body of the second and third generation models. The original models used single stone weights added to the bodies during the stuffing process.

## Crochet Pattern Notes

The crochet patterns use the English notation.

### Abbreviations

(ch)	=	chain stitch
(dc)	=	double crochet - this is equivalent to the American single crochet
(dec)	=	decrease is made by:- passing the hook into the next stitch and pulling the wool through which gives two threads on the hook; then passing the hook into the next stitch and pulling the wool through, which gives three threads on the hook; then put the wool over the hook and pull it through all three threads on the hook, leaving just one.
(inc)	=	increase is made by making two double crochets into the same stitch.
(rnd)	=	round
(row)	=	row
(rpt)	=	repeat
(ss)	=	slip stitch
(st)	=	stitch

The models are made by crochet rounds instead of rows. With the best effort in the world, it is very easy to lose count of how many stitches have been completed on a round and so it is therefore very helpful to mark the start of each round. This can be readily done by using a bodkin to thread a small piece of different colour wool through the start stitch of each new round.

The picture below shows a first generation quark body with the starts of rounds marked with pieces of coloured wool.



## Crochet patterns

### First generation body.

Double knit wool, 4.5mm crochet hook.

Make a loop of yarn, with the tail hanging downwards and the working yarn overlapping in front of the tail.

Holding the loop in place, insert the hook through the centre of the loop and pull the working yarn through the loop.

Make 1 chain.

Rnd 1:- Work 6dc into loop, ensuring that they go over the tail.

Pull tail to close the loop together. (6)

Rnd 2:- Work 2dc into each dc around the loop (12)

Rnd 3:- (dc, 2dc into next stitch) 5 times more (18)

Rnd 4:- (2dc, 2dc into next stitch) 5 times more (24)

Rnd 5:- (3dc, 2dc into next stitch) 5 times more (30)

Rnd 6:- (4dc, 2dc into next stitch) 5 times more (36)

Rnd 7:- (5dc, 2dc into next stitch) 5 times more (42)

Rnd 8:- (6dc, 2dc into next stitch) 5 times more (48)

Rnd 9:- 1dc into each stitch to end (48)

Rnd 10:- 8dc, 8ch, miss 8st, 16dc, 8ch, miss 8st, 8dc to end (48)

(This creates the two arm holes.)

Rnd 11:- 1dc into each stitch to end (48)

Rnd 12:- 1dc into each stitch to end (48)

Rnd 13:- 20dc, 8ch, miss 8st, 20dc to end (48)

(This creates the 'stuffing' hole.)

Rnd 14:- 1dc into each stitch to end (48)

Rnd 15:- (6dc, 1dec) 5 times more (42)

Rnd 16:- (5dc, 1dec) 5 times more (36)

Rnd 17:- (4dc, 1dec) 5 times more (30)

Rnd 18:- (3dc, 1dec) 5 times more (24)

Rnd 19:- (2dc, 1dec) 5 times more (18)

Rnd 20:- (1dc, 1dec) 5 times more (12)

Rnd 21:- 1dec, 5 times more (6)

Fasten off, leaving long tail. Pass tail through the 6 stitches, pull to close hole and fasten off.



## **Second generation body.**

Double knit wool, 4.5mm crochet hook.

Make a loop of yarn, with the tail hanging downwards and the working yarn overlapping in front of the tail.

Holding the loop in place, insert the hook through the centre of the loop and pull the working yarn through the loop.

Make 1 chain.

Rnd 1:- Work 6dc into loop, ensuring that they go over the tail.

Pull tail to close the loop together. (6)

Rnd 2:- Work 2dc into each dc around the loop (12)

Rnd 3:- (dc, 2dc into next stitch) 5 times more (18)

Rnd 4:- (2dc, 2dc into next stitch) 5 times more (24)

Rnd 5:- (3dc, 2dc into next stitch) 5 times more (30)

Rnd 6:- (4dc, 2dc into next stitch) 5 times more (36)

Rnd 7:- (5dc, 2dc into next stitch) 5 times more (42)

Rnd 8:- (6dc, 2dc into next stitch) 5 times more (48)

Rnd 9:- 1dc into each stitch to end (48)

Rnd 10:- 8dc, 8ch, miss 8st, 16dc, 8ch, miss 8st, 8dc to end (48)

(This creates the two arm holes.)

Rnd 11:- 1dc into each stitch to end (48)

Rnd 12:- 19dc, 10ch, miss 10st, 19dc to end (48)

(This creates the 'stuffing' hole.)

Rnd 13:- 1dc into each stitch to end (48)

Rnd 14:- 8dc, 8ch, miss 8st, 16dc, 8ch, miss 8st, 8dc to end (48)

(This creates the two arm holes.)

Rnd 15:- 1dc into each stitch to end (48)

Rnd 16:- (6dc, 1dec) 5 times more (42)

Rnd 17:- (5dc, 1dec) 5 times more (36)

Rnd 18:- (4dc, 1dec) 5 times more (30)

Rnd 19:- (3dc, 1dec) 5 times more (24)

Rnd 20:- (2dc, 1dec) 5 times more (18)

Rnd 21:- (1dc, 1dec) 5 times more (12)

Rnd 22:- 1dec, 5 times more (6)

Fasten off, leaving long tail. Pass tail through the 6 stitches, pull to close hole and fasten off.

### **Third generation body.**

Double knit wool, 4.5mm crochet hook.

Make a loop of yarn, with the tail hanging downwards and the working yarn overlapping in front of the tail.

Holding the loop in place, insert the hook through the centre of the loop and pull the working yarn through the loop.

Make 1 chain.

Rnd 1:- Work 6dc into loop, ensuring that they go over the tail.

Pull tail to close the loop together. (6)

Rnd 2:- Work 2dc into each dc around the loop (12)

Rnd 3:- (dc, 2dc into next stitch) 5 times more (18)

Rnd 4:- (2dc, 2dc into next stitch) 5 times more (24)

Rnd 5:- (3dc, 2dc into next stitch) 5 times more (30)

Rnd 6:- (4dc, 2dc into next stitch) 5 times more (36)

Rnd 7:- (5dc, 2dc into next stitch) 5 times more (42)

Rnd 8:- (6dc, 2dc into next stitch) 5 times more (48)

Rnd 9:- 1dc into each stitch to end (48)

Rnd 10:- 8dc, 8ch, miss 8st, 16dc, 8ch, miss 8st, 8dc to end (48)

(This creates the two arm holes.)

Rnd 11:- 1dc into each stitch to end (48)

Rnd 12:- 1dc into each stitch to end (48)

Rnd 13:- 8dc, 8ch, miss 8st, 16dc, 8ch, miss 8st, 8dc to end (48)

(This creates the two more arm holes.)

Rnd 14:- 1dc into each stitch to end (48)

Rnd 15:- 1dc into each stitch to end (48)

Rnd 16:- 8dc, 8ch, miss 8st, 16dc, 8ch, miss 8st, 8dc to end (48)

(This creates the two more arm holes.)

Rnd 17:- 1dc into each stitch to end (48)

Rnd 18:- 18dc, 12ch, miss 12st, 18dc to end (48)

(This creates the 'stuffing' hole.)

Rnd 19:- 1dc into each stitch to end (48)

Rnd 20:- (6dc, 1dec) 5 times more (42)

Rnd 21:- (5dc, 1dec) 5 times more (36)

Rnd 22:- (4dc, 1dec) 5 times more (30)

Rnd 23:- (3dc, 1dec) 5 times more (24)

Rnd 24:- (2dc, 1dec) 5 times more (18)

Rnd 25:- (1dc, 1dec) 5 times more (12)

Rnd 26:- 1dec, 5 times more (6)

Fasten off, leaving long tail. Pass tail through the 6 stitches, pull to close hole and fasten off.

## **Boson body.**

Double knit wool, 4.5mm crochet hook.

Make a loop of yarn, with the tail hanging downwards and the working yarn overlapping in front of the tail.

Holding the loop in place, insert the hook through the centre of the loop and pull the working yarn through the loop.

Make 1 chain.

Rnd 1:- Work 6dc into loop, ensuring that they go over the tail.

Pull tail to close the loop together. (6)

Rnd 2:- Work 2dc into each dc around the loop (12)

Rnd 3:- (dc, 2dc into next stitch) 5 times more (18)

Rnd 4:- (2dc, 2dc into next stitch) 5 times more (24)

Rnd 5:- (3dc, 2dc into next stitch) 5 times more (30)

Rnd 6:- (4dc, 2dc into next stitch) 5 times more (36)

Rnd 7:- (5dc, 2dc into next stitch) 5 times more (42)

Rnd 8:- (6dc, 2dc into next stitch) 5 times more (48)

Rnd 9:- 1dc into each stitch to end (48)

Rnd 10:- 1dc into each stitch to end (48)

Rnd 11:- 18dc, 12ch, miss 12st, 18dc to end (48)

(This creates the 'stuffing' hole.)

Rnd 12:- 1dc into each stitch to end (48)

Rnd 13:- 1dc into each stitch to end (48)

Rnd 14:- (6dc, 1dec) 5 times more (42)

Rnd 15:- (5dc, 1dec) 5 times more (36)

Rnd 16:- (4dc, 1dec) 5 times more (30)

Rnd 17:- (3dc, 1dec) 5 times more (24)

Rnd 18:- (2dc, 1dec) 5 times more (18)

Rnd 19:- (1dc, 1dec) 5 times more (12)

Rnd 20:- 1dec, 5 times more (6)

Fasten off, leaving long tail. Pass tail through the 6 stitches, pull to close hole and fasten off.



## Arms

For each arm.

Using crochet hook, pull wool through a stitch of one of the arm holes, leaving a long tail.

Make 1ch.

Rnd 1:- 1dc into each stitch around the arm hole - aim for 16.

(The number of stitches may vary depending on enthusiasm, often it is 20-22!)

Rnd 2:- 1dc into each stitch - adjust the number of stitches on this round by evenly spaced decreases to 16.

Rnd 3:- 1dc into each stitch around arm (16)

Rnd 4: - rpt rnd3 (16)

Rnd 5: - rpt rnd3 (16)

Rnd 6: - rpt rnd3 (16)

Rnd 7: - (2dc, 1dec) 3 times more (12)

Rnd 8: - 6dec (6)

Fasten off, leaving long tail. Pass tail through the 6 stitches, pull to close hole and sew in passing tail into the body. Sew in the beginning tail on the inside of the body.

## Eyes

Make a loop of yarn, with the tail hanging downwards and the working yarn overlapping in front of the tail.

Holding the loop in place, insert the hook through the centre of the loop and pull the working yarn through the loop.

Make 1 chain.

Rnd 1:- Work 6dc into loop, ensuring that they go over the tail.

Pull tail to close the loop together. (6)

Join with a slip stitch.

Fasten off, leaving a long tail.

Sew in around edge taking tail then into the centre with the other tail.

Use the two tails to sew to the body.

## Finishing off

Sew in all ends but leave the 'stuffing' hole open. Hide any tails from sewing in on the inside.

Carefully stuff the arms first and then begin to stuff the body. Add any weights to the body and then finish stuffing.

Sew up the 'stuffing' hole, hiding the tails inside the body.

Position any eyes across the body above the arms and sew in place, hiding the tails inside the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use the correct colour wool (black or red) to sew the particle symbol across the top.

## Neutrino body and arms.

Double knit wool, 4.5mm crochet hook.

Make a loop of yarn, with the tail hanging downwards and the working yarn overlapping in front of the tail.

Holding the loop in place, insert the hook through the centre of the loop and pull the working yarn through the loop.

Make 1 chain.

Rnd 1:- Work 6dc into loop, ensuring that they go over the tail.

Pull tail to close the loop together. (6)

Rnd 2:- Work 2dc into each dc around the loop (12)

Rnd 3:- (dc, 2dc into next stitch) 5 times more (18)

Rnd 4:- (2dc, 2dc into next stitch) 5 times more (24)

Rnd 5:- (3dc, 2dc into next stitch) 5 times more (30)

Rnd 6:- (4dc, 2dc into next stitch) 5 times more (36)

Rnd 7:- (5dc, 2dc into next stitch) 5 times more (42)

Rnd 8:- (6dc, 2dc into next stitch) 5 times more (48)

Rnd 9:- 9dc, 6ch, miss 6st, 18dc, 6ch, miss 6st, 9dc (48)

(This creates the 'arm' holes.)

Rnd 10:- 20dc, 8ch, miss 8st, 20dc to end (48)

(This creates the 'stuffing' hole.)

Rnd 11:- (6dc, 1dec) 5 times more (42)

Rnd 12:- (5dc, 1dec) 5 times more (36)

Rnd 13:- (4dc, 1dec) 5 times more (30)

Rnd 14:- (3dc, 1dec) 5 times more (24)

Rnd 15:- (2dc, 1dec) 5 times more (18)

Rnd 16:- (1dc, 1dec) 5 times more (12)

Rnd 17:- 1dec, 5 times more (6)

Fasten off, leaving long tail. Pass tail through the 6 stitches, pull to close hole and fasten off.

## Arms

For each arm.

Using crochet hook, pull wool through a stitch of one of the arm holes, leaving a long tail.

Make 1ch.

Rnd 1:- 1dc into each stitch around the arm hole - aim for 12.

(The number of stitches may vary depending on enthusiasm, often it is 14 - 16!)

Rnd 2:- 1dc into each stitch - adjust the number of stitches on this round by evenly spaced decreases to 12.

Rnd 3:- 1dc into each stitch around arm (12)

Rnd 4:- rpt rnd3 (12)

Rnd 5:- rpt rnd3 (12)

Rnd 6:- rpt rnd3 (12)

Rnd 7:- rpt rnd3 (12)

Rnd 8:- rpt rnd3 (12)

Rnd 9:- 6dec (6)

Fasten off, leaving long tail. Pass tail through the 6 stitches, pull to close hole and sew in passing tail into the body. Sew in the beginning tail on the inside of the body.

## **Neutrino coats and arms.**

### **Muon neutrino coat and arms**

Double knit wool, 4.5mm crochet hook.

Make 30 chains.

Form a loop by using a slip stitch to join the ends of the 30 chains (30)

Row 1: - 1ch, (4dc, 2dc into next stitch) 5 times more, 1ss to complete row (36)

Row 2: - 1ch, (5dc, 2dc into next stitch) 5 times more, 1ss to complete row (42)

Row 3: - 1ch, (6dc, 2dc into next stitch) 5 times more, 1ss to complete row (48)

Row 4: - 1ch, (7dc, 2dc into next stitch) 5 times more, 1ss to complete row (54)

Row 5: - 1ch, 9dc, 8ch, miss 8st, 2dc, 6ch, miss 6st, 3dc, 6ch, miss 6st, 2dc 8ch, miss 8st, 10dc, 1ss to complete row (54)

(This creates the holes for the neutrino arms to pass through plus two new arms.)

Row 6:- 1ch, (7dc, 1dec) 5 times more, 1ss to complete row (48)

Row 7:- 1ch, (6dc, 1dec) 5 times more, 1ss to complete row (42)

Row 8:- 1ch, (5dc, 1dec) 5 times more, 1ss to complete row (36)

Row 9:- 1ch, (4dc, 1dec) 5 times more, 1ss to complete row (30)

Fasten off, leaving long tail. Sew this tail into the edge.

Sew in the beginning tail into its edge.

### **Arms**

For each arm.

Using crochet hook, pull wool through a stitch of one of the arm holes, leaving a long tail.

Make 1ch.

Rnd 1:- 1dc into each stitch around the arm hole - aim for 12.

(The number of stitches may vary depending on enthusiasm, often it is 14 - 16!)

Rnd 2:- 1dc into each stitch - adjust the number of stitches on this round by evenly spaced decreases to 12.

Rnd 3:- 1dc into each stitch around arm (12)

Rnd 4: - rpt rnd3 (12)

Rnd 5: - rpt rnd3 (12)

Rnd 6: - rpt rnd3 (12)

Rnd 7: - rpt rnd3 (12)

Rnd 8: - 6dec (6)

Fasten off, leaving long tail. Pass tail through the 6 stitches, pull to close hole and sew in passing tail into the body. Sew in the beginning tail on the inside of the body.

### **Internal arm cover**

**Two** are required.

Follow the first two rounds of the neutrino body (12)

Fasten off, leaving long tail. Sew some of this tail into the edge and leave the rest of the tail for sewing in to the coat.

Sew in the beginning tail into the centre.

## **Tauon neutrino coat and arms**

Double knit wool, 4.5mm crochet hook.

Make 30 chains.

Form a loop by using a slip stitch to join the ends of the 30 chains (30)

Row 1: - 1ch, (4dc, 2dc into next stitch) 5 times more, 1ss to complete row (36)

Row 2: - 1ch, (5dc, 2dc into next stitch) 5 times more, 1ss to complete row (42)

Row 3: - 1ch, (6dc, 2dc into next stitch) 5 times more, 1ss to complete row (48)

Row 4: - 1ch, (7dc, 2dc into next stitch) 5 times more, 1ss to complete row (54)

Row 5: - 1ch, (8dc, 2dc into next stitch) 5 times more, 1ss to complete row (60)

Row 6: - 1ch, 3dc, 6ch, miss 6st, 2dc, 8ch, miss 8st, 2dc, 8ch, miss 8st, 3dc, 8ch, miss 8st, 2dc, 8ch, miss 8st, 2dc, 6ch, miss 6st, 2dc, 1ss to complete row (60)

(This creates the holes for the neutrino arms to pass through plus two new arms.)

Row 7:- 1ch, (8dc, 1dec) 5 times more, 1ss to complete row (54)

Row 8:- 1ch, (7dc, 1dec) 5 times more, 1ss to complete row (48)

Row 9:- 1ch, (6dc, 1dec) 5 times more, 1ss to complete row (42)

Row 10:- 1ch, (5dc, 1dec) 5 times more, 1ss to complete row (36)

Fasten off, leaving long tail. Sew this tail into the edge.

Sew in the start tail into its edge.

## **Arms**

For each arm.

Using crochet hook, pull wool through a stitch of one of the arm holes, leaving a long tail.

Make 1ch.

Rnd 1:- 1dc into each stitch around the arm hole - aim for 12.

(The number of stitches may vary depending on enthusiasm, often it is 14 - 16!)

Rnd 2:- 1dc into each stitch - adjust the number of stitches on this round by evenly spaced decreases to 12.

Rnd 3:- 1dc into each stitch around arm (12)

Rnd 4: - rpt rnd3 (12)

Rnd 5: - rpt rnd3 (12)

Rnd 6: - rpt rnd3 (12)

Rnd 7: - 6dec (6)

Fasten off, leaving long tail. Pass tail through the 6 stitches, pull to close hole and sew in passing tail into the body. Sew in the beginning tail on the inside of the body.

## **Internal arm cover**

**Two** are required.

Follow the first two rounds of the neutrino body (12)

Fasten off, leaving long tail. Sew some of this tail into the edge and leave the rest of the tail for sewing in to the coat.

Sew in the start tail into the centre.

## LEPTONS Electron.

Use green wool to make a FIRST generation body.

Crochet the two arms to the body, stuff and then sew up.

Make three BLACK eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use BLACK wool to sew an  $e^-$  across the top of the electron.



## Positron. (Anti-electron)

Use green wool to make a FIRST generation body.

Crochet the two arms to the body, stuff and then sew up.

Make three RED eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use RED wool to sew an  $e^+$  across the top of the positron.



## Muon.

Use green wool to make a SECOND generation body.

Crochet the four arms to the body.

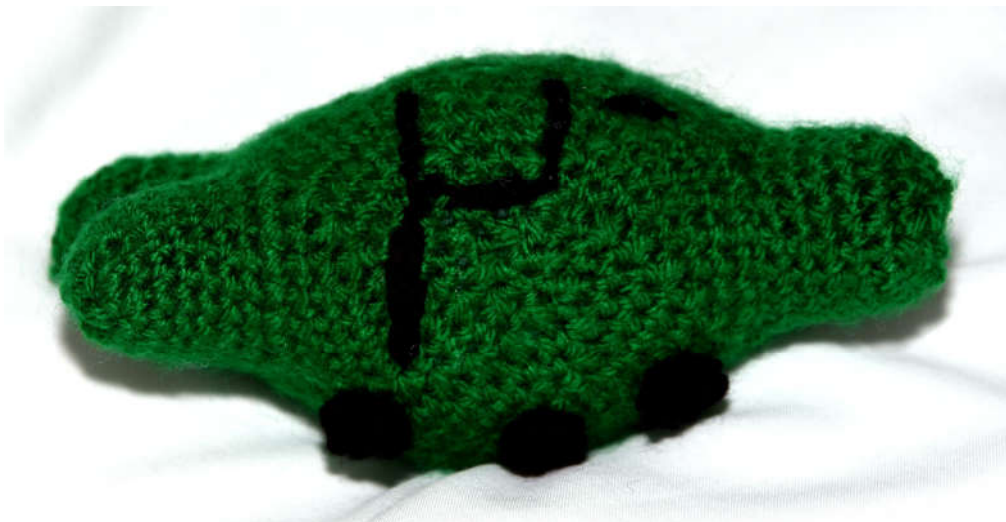
Stuff the arms and then begin to stuff the body.

Add approximately 100g of weight, finish stuffing and then sew up.

Make three BLACK eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use BLACK wool to sew an  $\mu^-$  across the top of the muon.





## Anti-Muon.

Use green wool to make a SECOND generation body.

Crochet the four arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 100g of weight, finish stuffing and then sew up.

Make three RED eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use RED wool to sew a  $\mu^+$  across the top of the anti-muon.

## Tauon.

Use green wool to make a THIRD generation body.

Crochet the six arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 200g of weight, finish stuffing and then sew up.

Make three BLACK eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use BLACK wool to sew an  $\tau^-$  across the top of the tauon.



## Anti-Tauon.

Use green wool to make a THIRD generation body.

Crochet the six arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 200g of weight, finish stuffing and then sew up.

Make three RED eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use RED wool to sew an  $\tau^+$  across the top of the anti-tauon.

## QUARKS

### Up quark

Use brown wool to make a FIRST generation body.

Crochet the two arms to the body.

Stuff the arms and then the body.

Sew up.

Make two RED eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use RED wool to sew an **U** across the top of the up quark.



## Anti-Up quark

Use brown wool to make a FIRST generation body.

Crochet the two arms to the body.

Stuff the arms and then the body.

Sew up.

Make two BLACK eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use BLACK wool to sew an u across the top of the anti-up quark.





## Down quark

Use brown wool to make a FIRST generation body.

Crochet the two arms to the body.

Stuff the arms and then the body.

Sew up.

Make one BLACK eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use BLACK wool to sew an **d** across the top of the down quark.



## Anti-down quark

Use brown wool to make a FIRST generation body.

Crochet the two arms to the body.

Stuff the arms and then the body.

Sew up.

Make one RED eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use RED wool to sew an d across the top of the anti-down quark.





## Strange quark

Use brown wool to make a SECOND generation body.

Crochet the four arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 100g of weight, finish stuffing and then sew up.

Make one BLACK eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use Black wool to sew an **S** across the top of the strange quark.



## Anti-strange quark

Use brown wool to make a SECOND generation body.

Crochet the four arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 100g of weight, finish stuffing and then sew up.

Make one RED eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eye.

Above the eye, use RED wool to sew an **S** across the top of the strange quark.

## Charm quark

Use brown wool to make a SECOND generation body.

Crochet the four arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 200g of weight, finish stuffing and then sew up.

Make two RED eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use RED wool to sew an **C** across the top of the charm quark.



## Anti-charm quark

Use brown wool to make a SECOND generation body.

Crochet the four arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 200g of weight, finish stuffing and then sew up.

Make two BLACK eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use BLACK wool to sew an **C** across the top of the anti-charm quark.



## Bottom quark

Use brown wool to make a THIRD generation body.

Crochet the six arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 200g of weight, finish stuffing and then sew up.

Make one BLACK eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eye.

Above the eye, use BLACK wool to sew an **b** across the top of the bottom quark.



## Anti-bottom quark

Use brown wool to make a THIRD generation body.

Crochet the six arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 200g of weight, finish stuffing and then sew up.

Make one RED eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eye.

Above the eye, use RED wool to sew an **b** across the top of the anti-bottom quark.

## Top quark

Use brown wool to make a THIRD generation body.

Crochet the six arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 300g of weight, finish stuffing and then sew up.

Make two RED eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use RED wool to sew an **t** across the top of the top quark.





## Anti-top quark

Use brown wool to make a THIRD generation body.

Crochet the six arms to the body.

Stuff the arms and then begin to stuff the body.

Add approximately 300g of weight, finish stuffing and then sew up.

Make two BLACK eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use BLACK wool to sew an t across the top of the anti top quark.

## $W^-$ boson

Use blue wool to make a BOSON body.

Begin to stuff the body.

Add approximately 200g of weight, finish stuffing and then sew up.

Make three BLACK eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use BLACK wool to sew an  $W^-$  across the top of the  $w^-$  boson.



## $W^+$ boson

Use blue wool to make a BOSON body.

Begin to stuff the body.

Add approximately 200g of weight, finish stuffing and then sew up.

Make three RED eyes and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eyes.

Above the eyes, use RED wool to sew an  $W^+$  across the top of the  $w^+$  boson.



## Z boson

Use blue wool to make a BOSON body.

Begin to stuff the body.

Add approximately 200g of weight, finish stuffing and then sew up.

Make one yellow eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eye.

Above the eye, use YELLOW wool to sew an **Z** across the top of the Z boson.





## Higg's boson

Two different shades of blue wool were used to make this particle.

Start with the same shade of blue wool as for the other bosons and crochet the first 8 rounds of the BOSON body.

Change to the other shade of blue for the next 5 rounds.

Change to the original shade of blue for the final 6 rounds (Rnd 14 to Rnd 20)

Begin to stuff the body.

Add approximately 300g of weight, finish stuffing and then sew up.

Make one yellow eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eye.

Above the eye, use YELLOW wool to sew an **H** across the top of the Higg's boson.



## Electron neutrino

Use green wool to make a neutrino body.

Crochet the two arms to the body, stuff and then sew up.

Make one YELLOW eye and sew onto the body.

Use ORANGE wool, sew a 'mouth' below the eye.



Since the neutrino models are smaller than any of the others, and are to take 'coats' for the other generations, it was decided not to make the labelling follow round from the front but to make it independent.

On the rear of the electron neutrino, use YELLOW wool to sew a Greek letter  $\nu$  and a subscripted letter  $e$ . The  $e$  should be positioned so that it is hidden when the muon neutrino coat is fitted.



## Electron anti-neutrino

Use green wool to make a neutrino body.

Crochet the two arms to the body, stuff and then sew up.

Make one GREEN eye and over sew around the edge with YELLOW wool, hiding the ends under the over sewing. Sew the eye onto the body.

Use ORANGE wool, sew a 'mouth' below the eye.



Since the neutrino models are smaller than any of the others, and are to take 'coats' for the other generations, it was decided not to make the labelling follow round from the front but to make it independent.

On the rear of the electron anti-neutrino, use YELLOW wool to sew a Greek letter  $\bar{\nu}$  and a subscripted letter  $e$ . The  $e$  should be positioned so that it is hidden when the muon neutrino coat is fitted.





## Muon neutrino

A muon neutrino is formed by adding a muon neutrino coat to the electron neutrino.

Use green wool to make a muon neutrino coat.

Crochet the two arms to the coat and sew in the tails.

Crochet two internal arm covers.



Stuff the two arms and then sew an internal arm cover over the inside of each arm to stop the stuffing escaping.



Along side the right arm hole and right leg, use YELLOW wool to sew a Greek letter  $\mu$ . This is then the rear side of the muon neutrino coat.



The muon neutrino coat is fitted to the electron neutrino by passing the electron neutrino arms through the two holes in the coat.



Rear of muon neutrino.



The muon neutrino coat can also be fitted to the anti-neutrino forming an anti-muon neutrino



Rear of anti-muon neutrino





## Tauon neutrino

A tauon neutrino is formed by adding a tauon neutrino coat to the muon neutrino.

Use green wool to make a tauon neutrino coat.

Crochet the two arms to the coat and sew in the tails.

Crochet two internal arm covers.

Stuff the two arms and then sew an internal arm cover over the inside of each arm to stop the stuffing escaping.



Turn the tauon neutrino coat so that the smaller opening is on the top. Along side the right arm hole and right leg hole, use YELLOW wool to sew a Greek letter  $\tau$ . This is then the rear side of the tauon neutrino coat.



The tauon neutrino coat is fitted to the muon neutrino by passing the muon neutrino arms through the four holes in the coat.



The muon neutrino can be seen inside the tauon neutrino coat and the electron neutrino inside the muon neutrino coat.



A tauon anti-neutrino can be made by fitting the tauon neutrino coat to the muon anti-neutrino.



## Standard Model Particles

Particle	Colour	Mass	Mev/c <sup>2</sup>	Eyes	Legs	AntiParticle	Colour	Mass	Eyes	Legs
<b>Leptons</b>						<b>Leptons</b>				
Electron	Green	25g	0.511	3 black	2	Electron/Positron	Green	25g	3 red	2
E neutrino	Green	25g		1 yellow		E neutrino	Green	25g		
Muon	Green	125g	105.7	3 black	4	Muon	Green	125g	3 red	4
M neutrino	Green	25g		1 yellow		M neutrino	Green	25g		
Tau	Green	225g	1777	3 black	6	Tau	Green	225g	3 red	6
T neutrino	Green	25g		1 yellow		T neutrino	Green	25g		
<b>Quarks</b>						<b>Quarks</b>				
Up	Brown	25g	1.7 - 3.3	2 red	2	Up	Brown	25g	2 black	2
Down	Brown	25g	4.1 - 5.8	1 black	2	Down	Brown	25g	1 red	2
Strange	Brown	125g	95	1 black	4	Strange	Brown	125g	1 red	4
Charm	Brown	225g	1280	2 red	4	Charm	Brown	225g	2 black	4
Bottom	Brown	225g	4400	1 black	6	Bottom	Brown	225g	1 red	6
Top	Brown	325g	173000	2 red	6	Top	Brown	325g	2 black	6
<b>Bosons</b>										
Higgs	Sparkly	325g	125000	1 yellow						
W+	Blue	225g	2100	3 red						
W-	Blue	225g	2100	3 black						
Z	Blue	225g	2250	1 yellow						
Gluon		25g								
Photon		25g								