



# Particle Physics in the International Baccalaureate Diploma (IB)

A CERN HST-2010  
working group proposal



# IB Diploma programme

- Pre-university education for 16 → 19 year olds
- > 500,000 graduates since 1970
- 2183 schools in 138 countries
- All students must study at least one science (group 4) subject at Standard or Higher Level



# IB Physics

- **Standard level:** 110 hours  
80 hours CORE +  
2 x 15 hour **OPTIONS**
- **Higher Level:** 180 hours  
135 hours CORE +  
2 x 22 hours **OPTIONS**
- Plus **Lab** hours  
(SL = 40 hours; HL = 60 hours)



# Lab work in Particle Physics?

- “IA activities should ideally include a spread of content material from the core, **options** and, where relevant, AHL material.”
- “A minimum number of investigations to be carried out is not specified.”



# How much lab work?

- Not specified
- Each option takes 22 / 180 total theory teaching hours (~12%)
  - ⇒ we should aim for 12% x 50 hours of total lab (*not including group 4 project*)
  - ⇒ approx. **6 hours** for particle physics at Higher Level!
- Can include computer simulations / database tasks



# it's a free market...

**HL options** (*select any 2*):

- Astrophysics
- Communications
- Electromagnetic waves
- Relativity
- Medical physics
- **Particle physics**



# Teachers might not choose particle physics because:

- It is a new option (2009)  
⇒ few example questions
- It is outside their specialist area of knowledge
- There are few good quality teaching resources available
- What to do for lab work?



# aim of this project

... to produce a single, coherent, high quality set of teaching resources:

- PowerPoint
- Worksheets
- Suggestions for lab work
- Homework sheets
- Exemplars
- Extension materials

... to encourage more teachers to offer particle physics

... to improve the quality of teaching and learning in particle physics





## A 2-way resource:

- From syllabus statements to content  
*(recognising that the IB syllabus booklet is the **prime document** for IB teachers)*
- A storyboard approach: telling the tale of particle physics  
*(a new CERN-branded course that covers all IB criteria in a more engaging way)*



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# Syllabus to content...

- J1: Particles & interactions
- J2: Particle accelerators & detectors
- J3: Quarks
- J4: Leptons & the standard model
- J5: Experimental evidence for the quark & standard models
- J6: Cosmology & strings

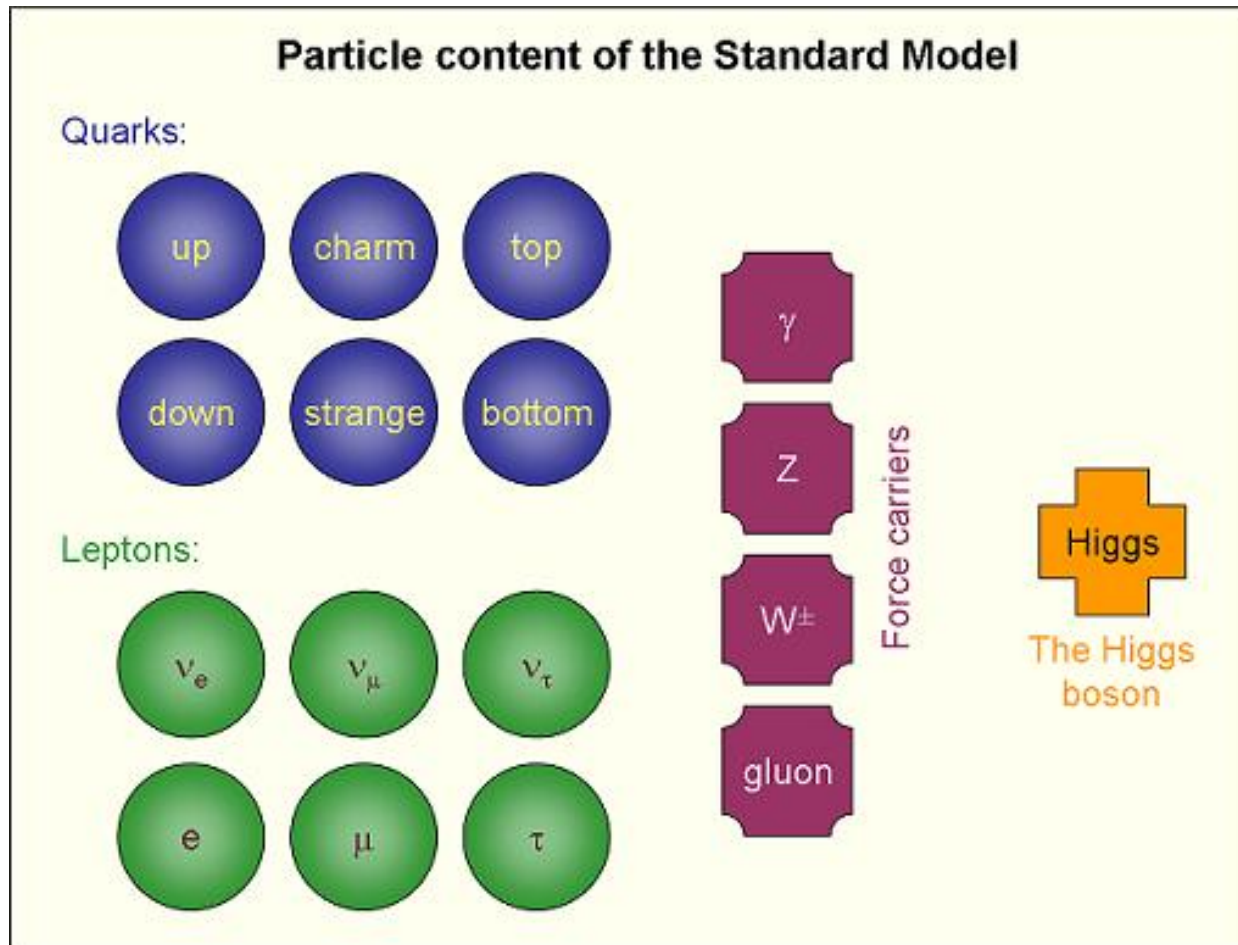


# J1: Particles & interactions

- J1.1: State what is meant by an elementary particle
- [J1.2](#): Identify elementary particles
- J1.3: Describe particles in terms of mass and various quantum numbers
- J1.4: Classify particles according to spin
- J1.5: State what is meant by an antiparticle
- J1.6: State the Pauli exclusion principle
- J1.7: List the fundamental interactions
- J1.8: Describe the fundamental interactions in terms of exchange particles
- J1.9: Discuss the uncertainty principle for time and energy in the context of particle creation

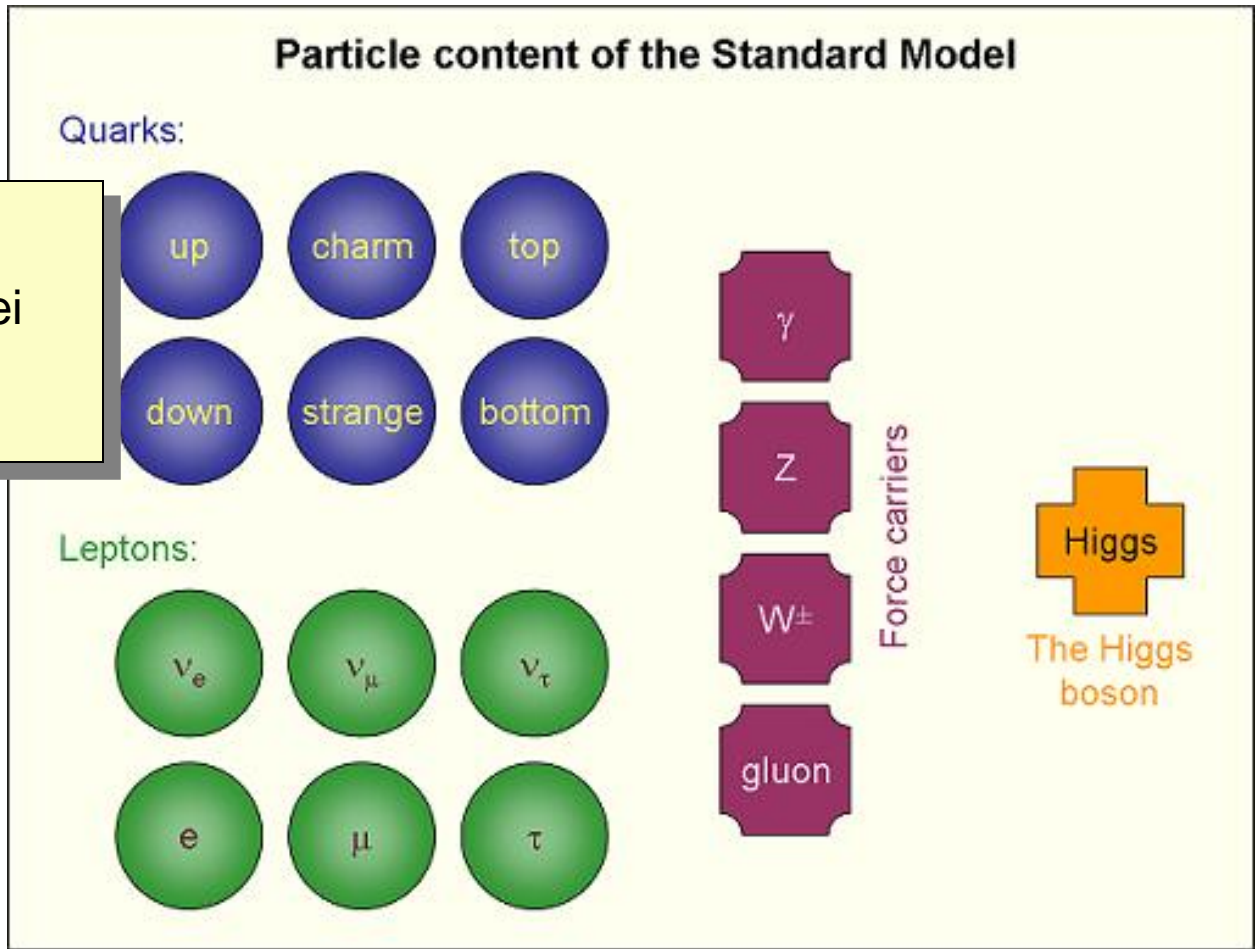


# J1.2: Identify elementary particles



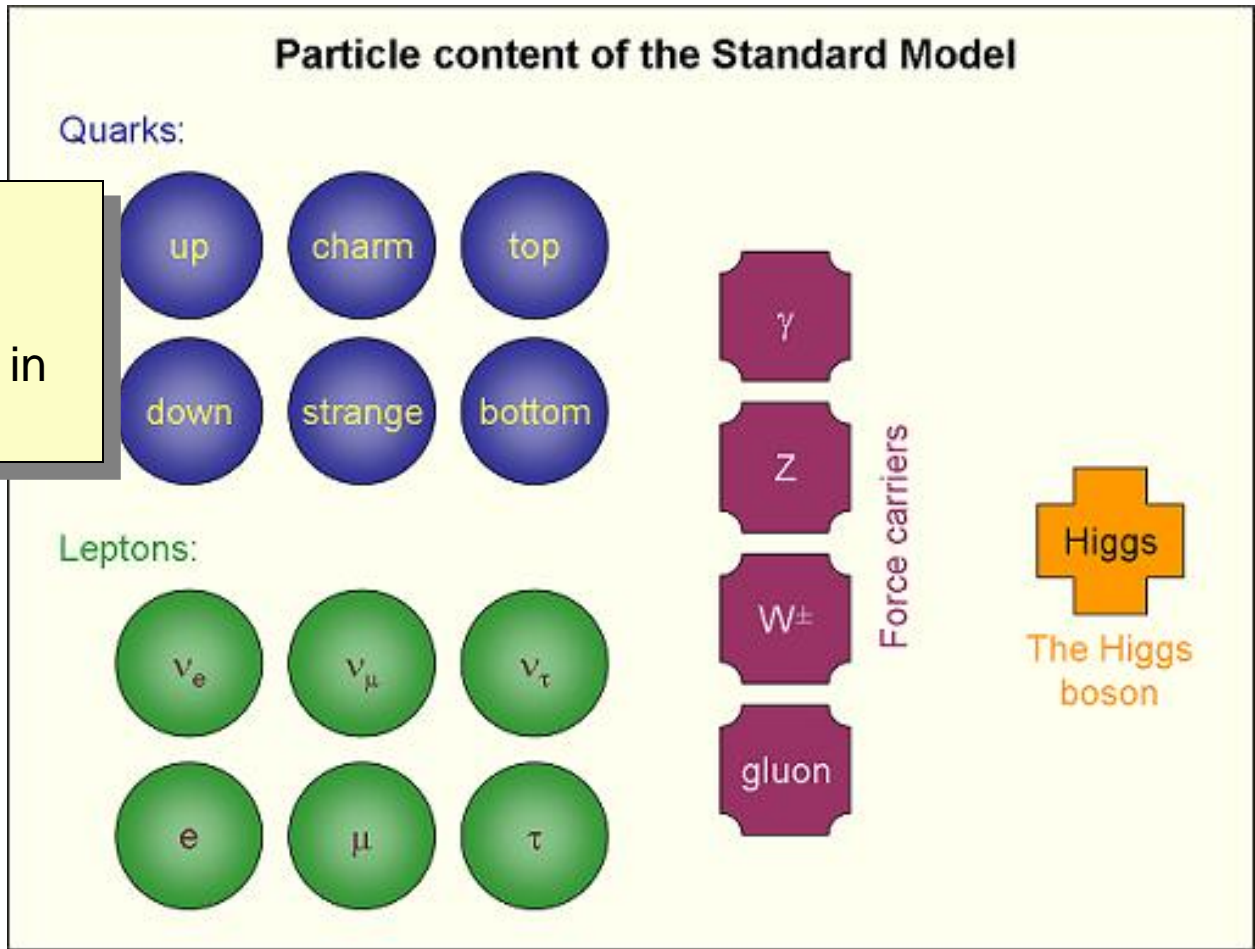
# J1.2: Identify elementary particles

**QUARKS:**  
Atomic nuclei  
are made of  
these



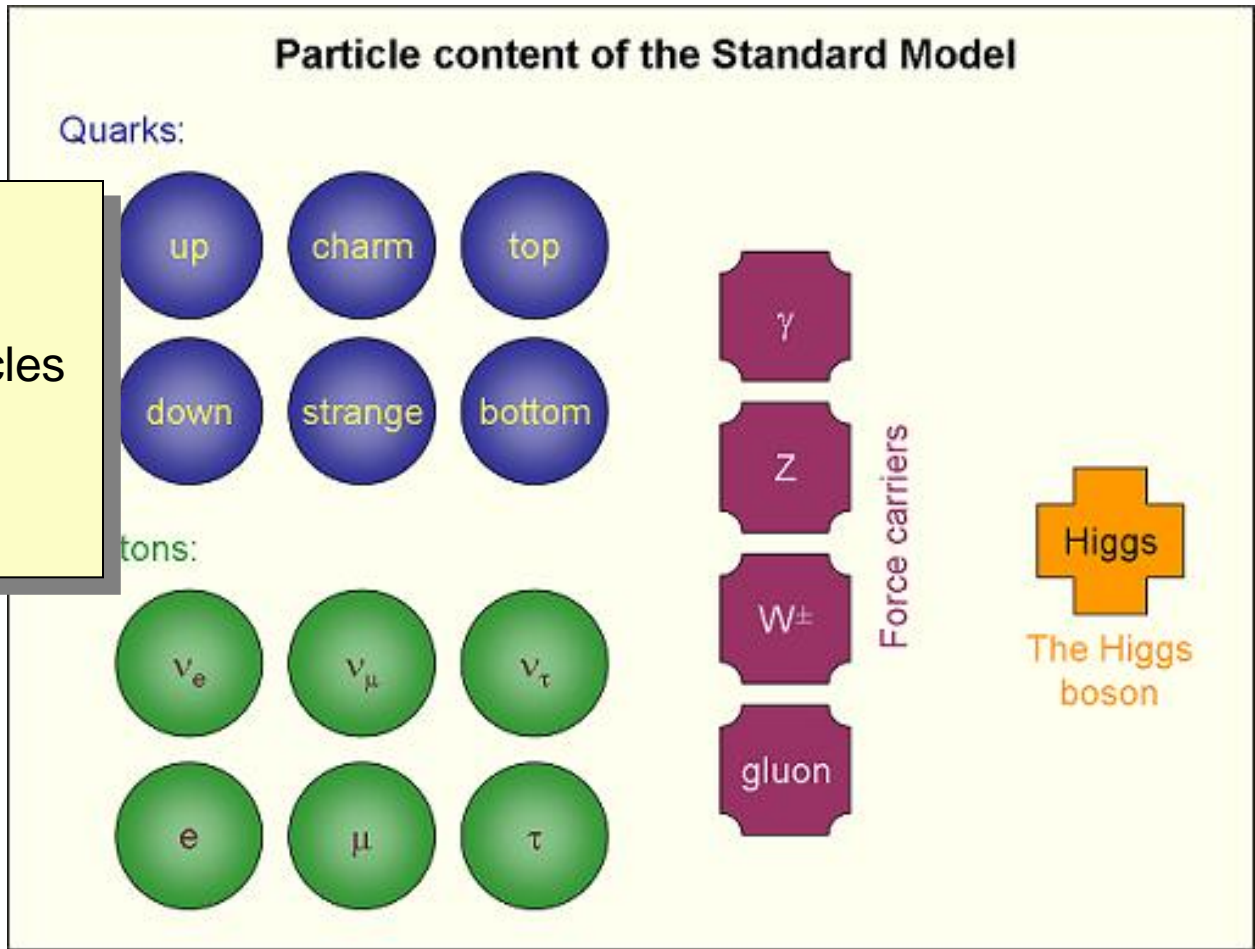
# J1.2: Identify elementary particles

**QUARKS:**  
“feel” every known force in nature



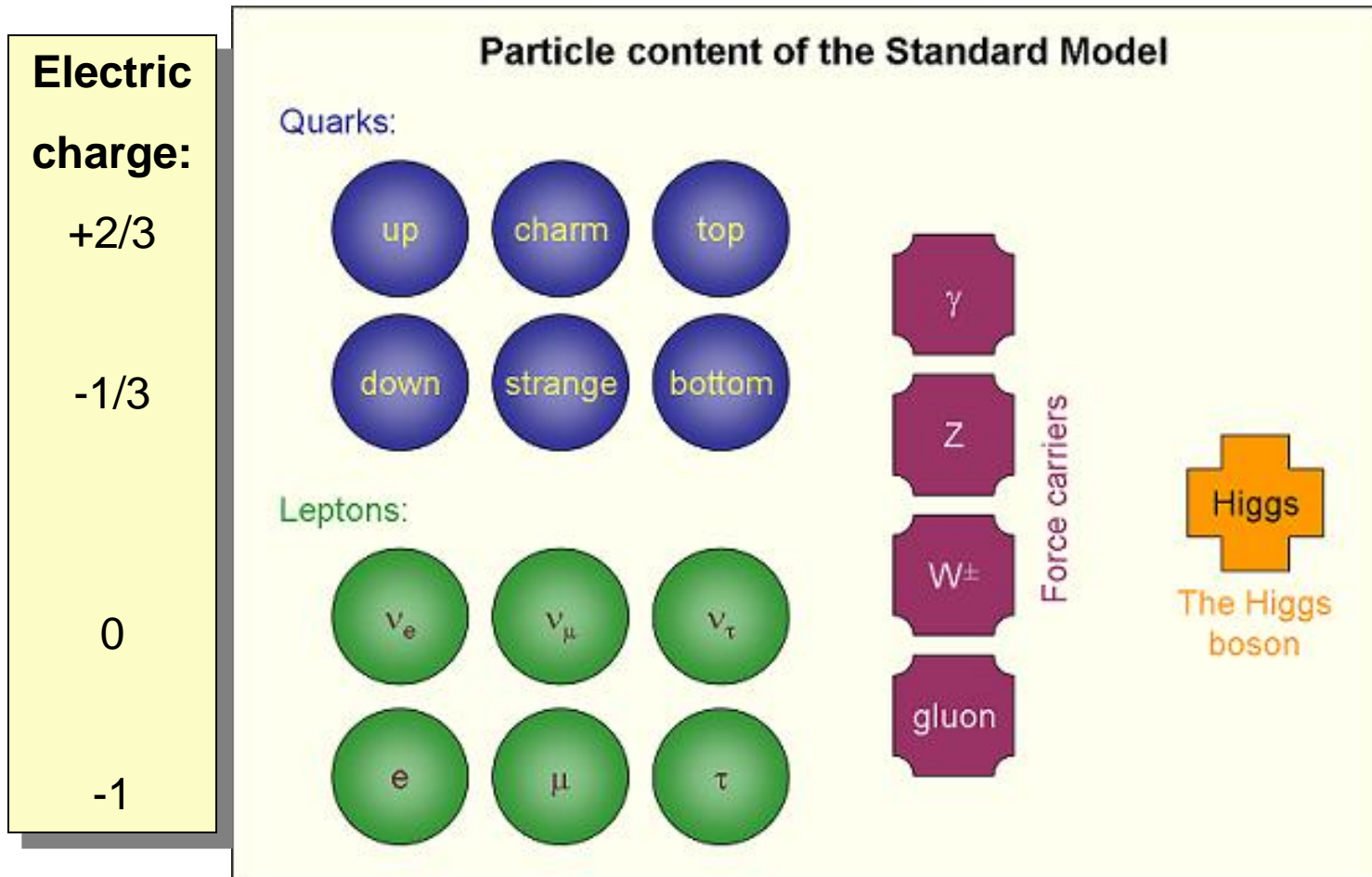
# J1.2: Identify elementary particles

**QUARKS:**  
are the only matter particles to “feel” the strong force

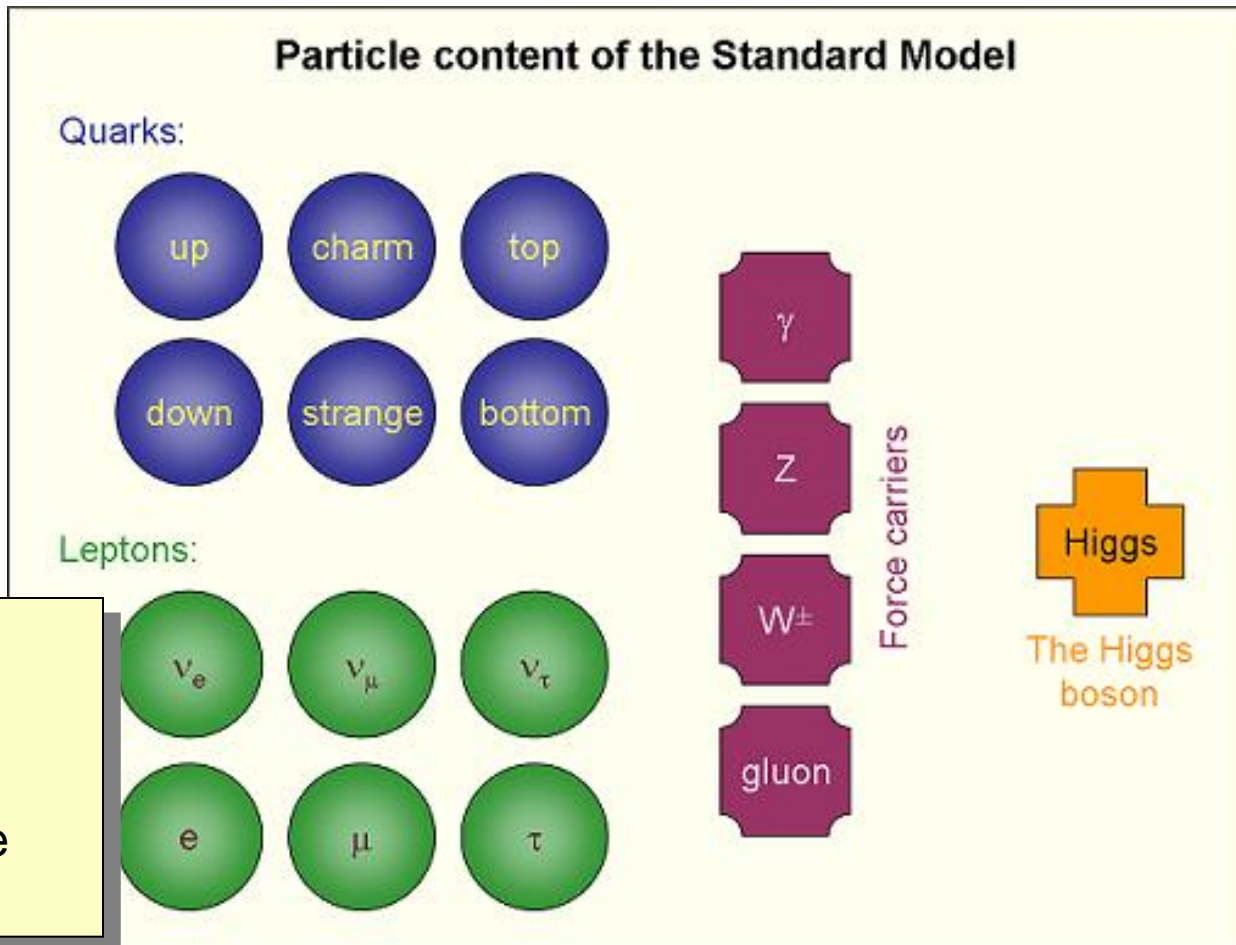




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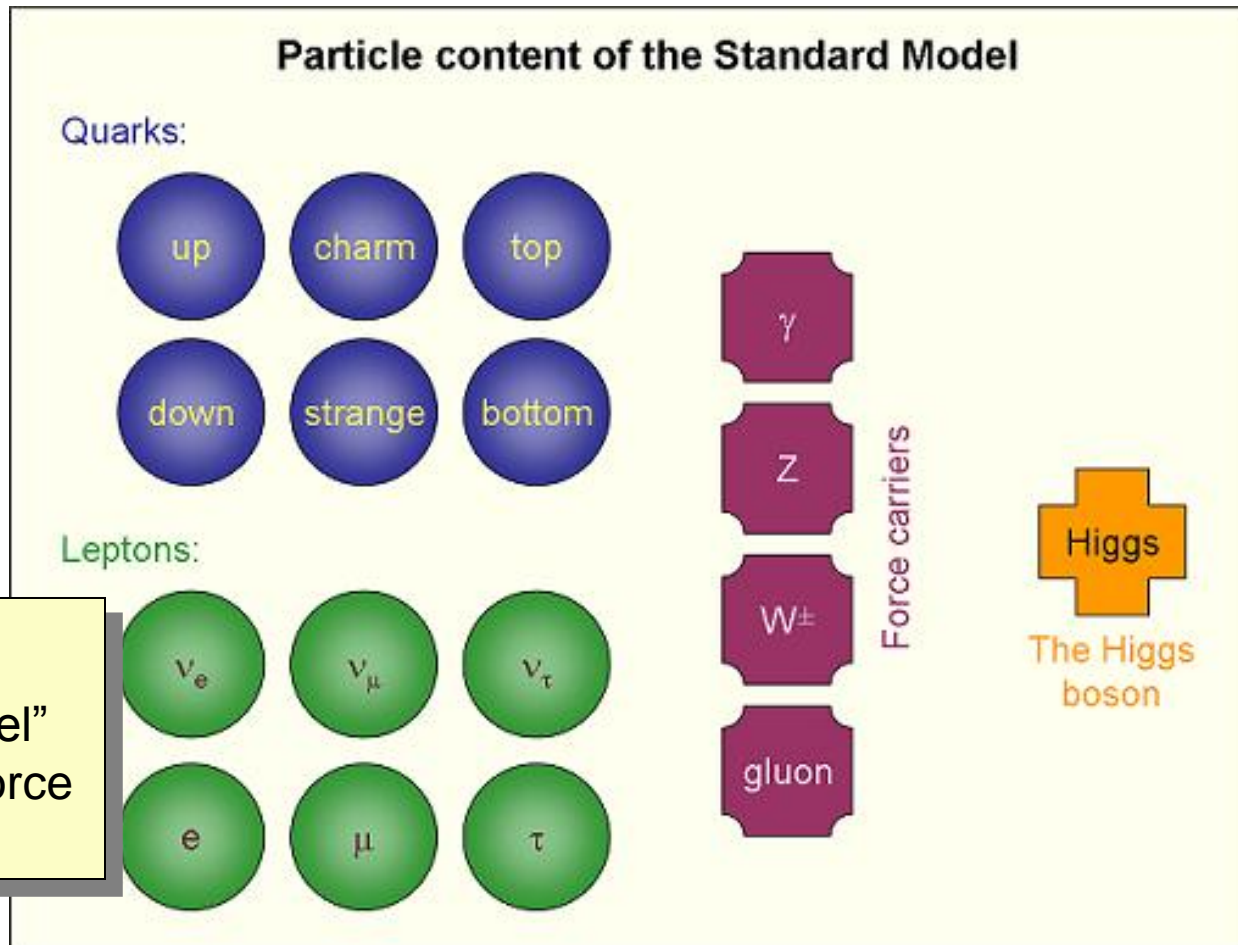


# J1.2: Identify elementary particles



**Leptons:**  
Are found everywhere EXCEPT the nucleus

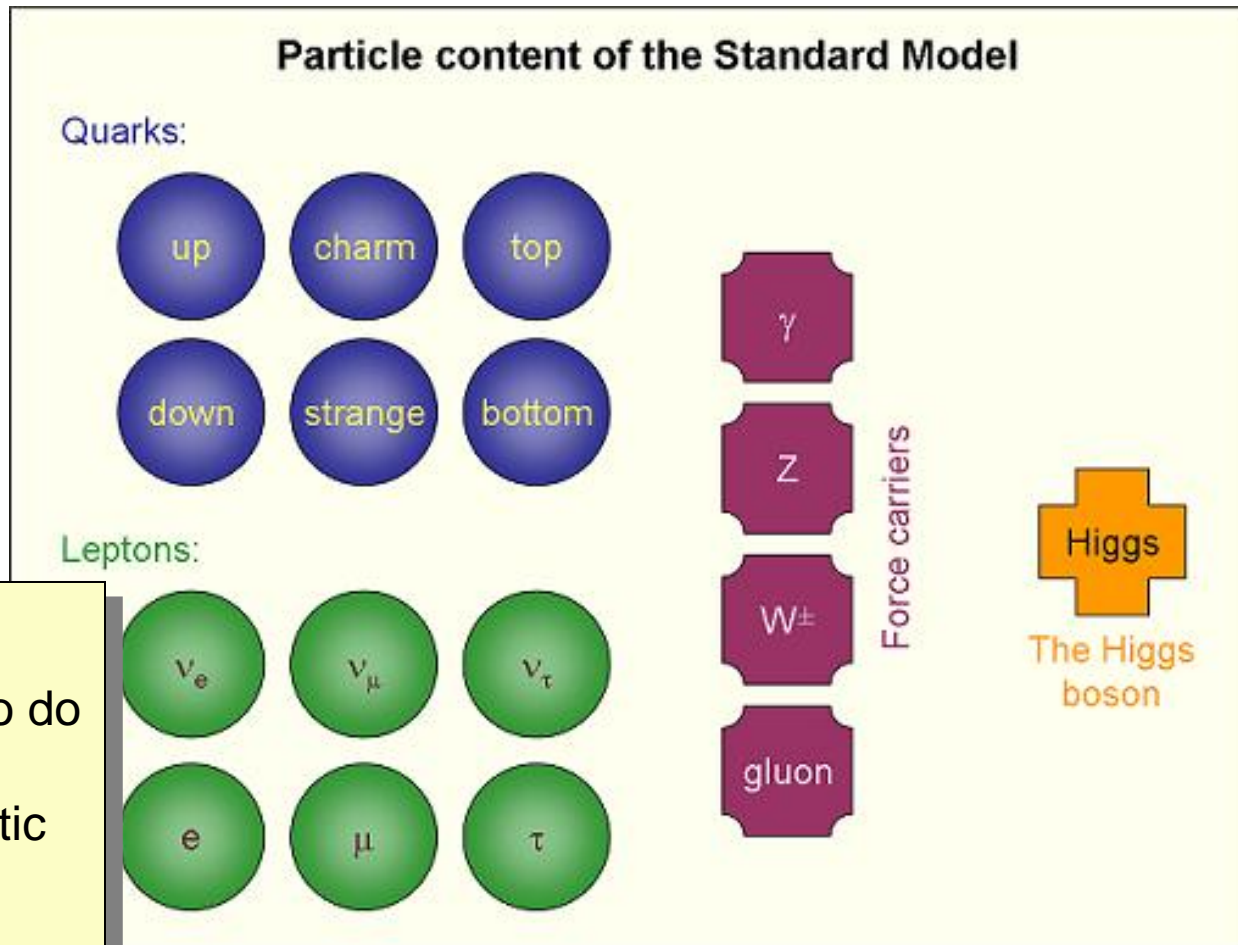
# J1.2: Identify elementary particles



**Leptons:**

DO NOT “feel”  
the strong force

# J1.2: Identify elementary particles




## Leptons:

Neutrinos also do not “feel” the electromagnetic force

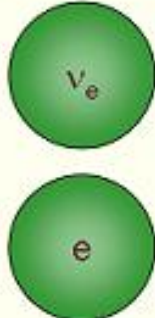
# J1.2: Identify elementary particles

**Particle content of the Standard Model**

Quarks:



Leptons:



**The first family:**  
All of the visible matter in the universe is made of these four particles.

**Nothing else is needed.**

So who ordered these -> ...?

# J1.2: Identify elementary particles

**Particle content of the Standard Model**

**Meet the neighbours:**  
Say hi to families  
2 & 3  
They are identical to  
family 1 - except each  
particle is heavier  
So... the Muon is a  
heavy electron

	charm	top
	strange	bottom
	$\nu_{\mu}$	$\nu_{\tau}$
	$\mu$	$\tau$



# J1.2: Identify elementary particles

**Particle content of the Standard Model**

Quarks:

up	charm	top
down	strange	bottom

Leptons:

$\nu_e$	$\nu_\mu$	$\nu_\tau$
e	$\mu$	$\tau$

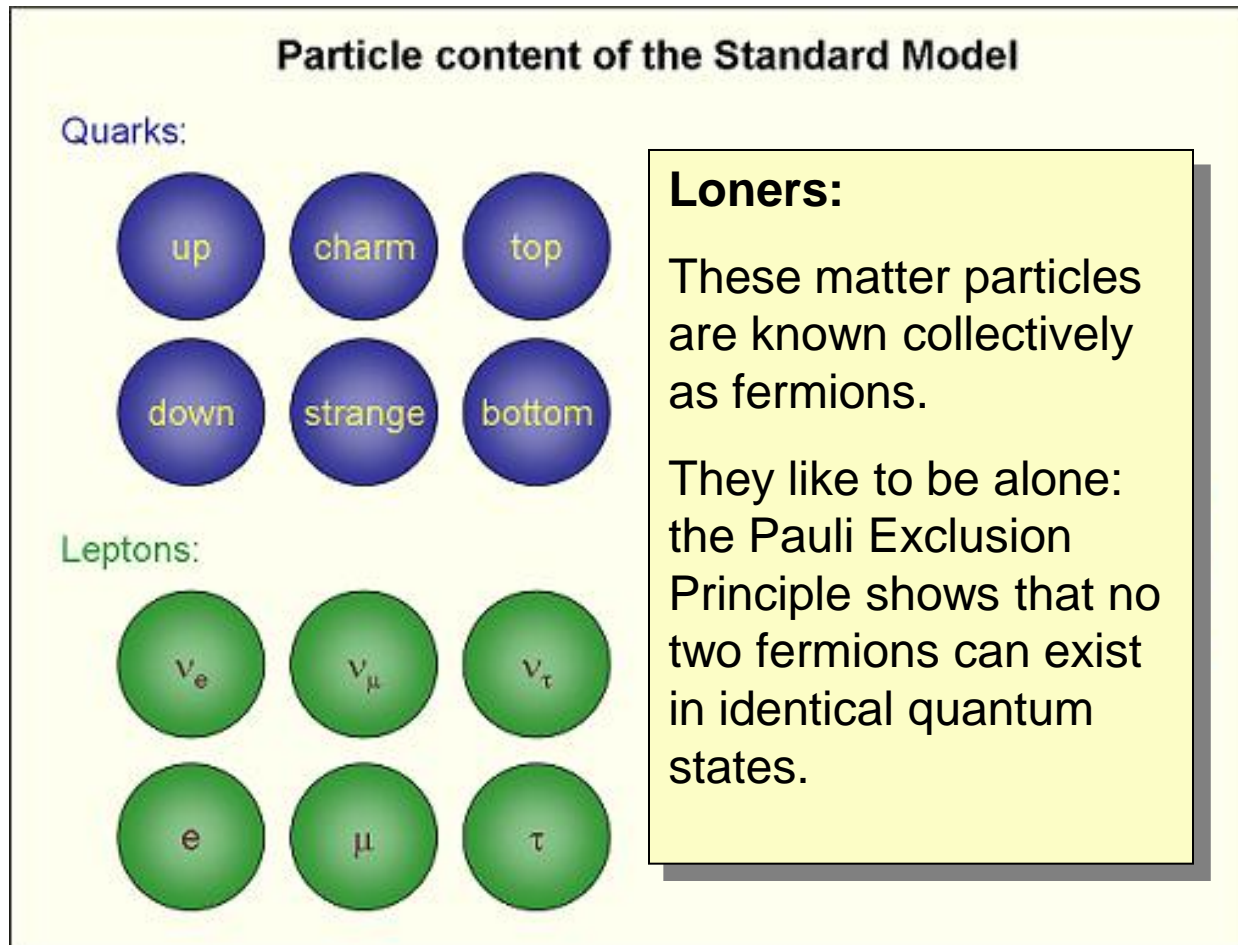
**THREE is the number:**

The heavy families disappeared as the universe cooled.

We don't know why these extra families of particles exist.

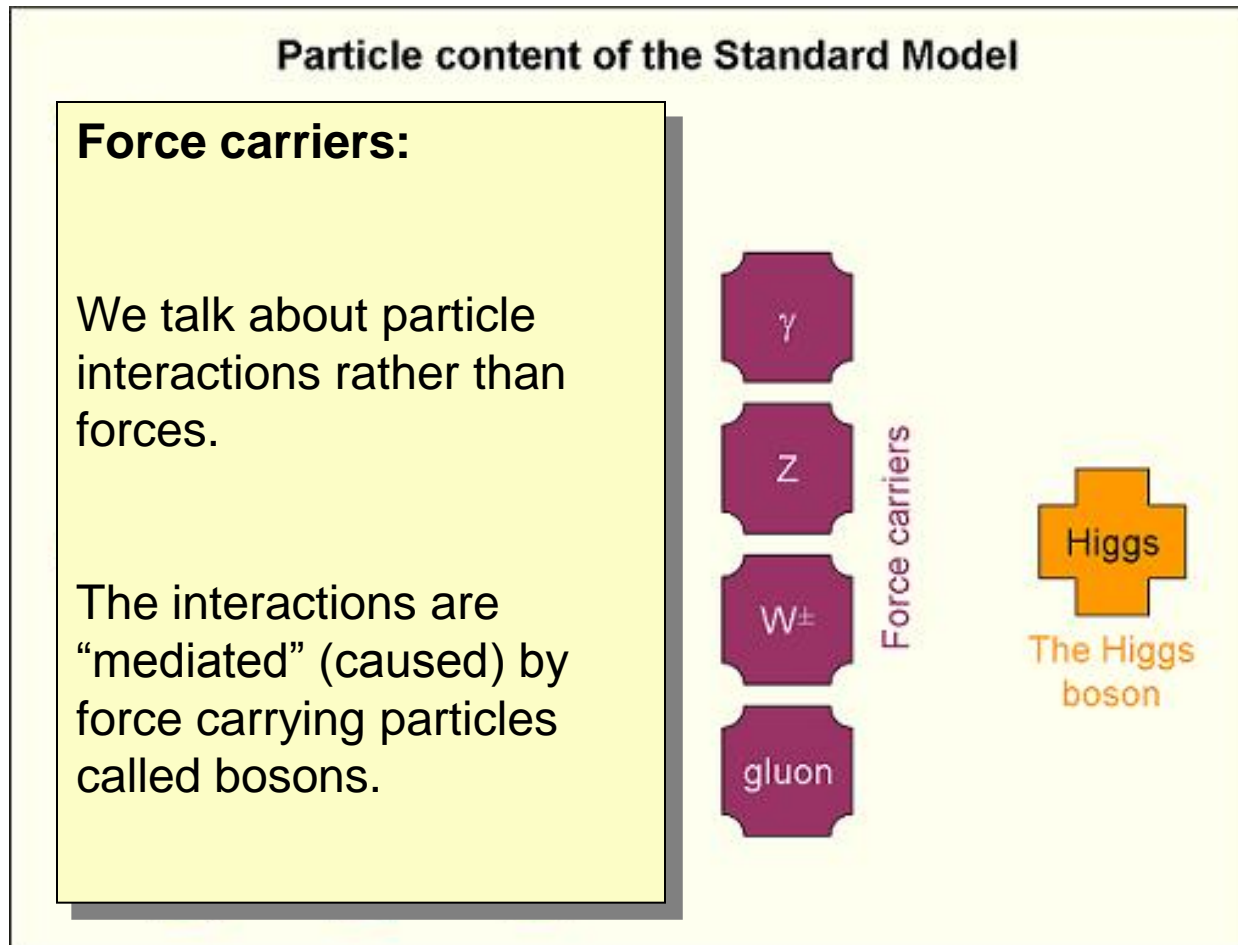
But we DO know that no other families exist.

# J1.2: Identify elementary particles

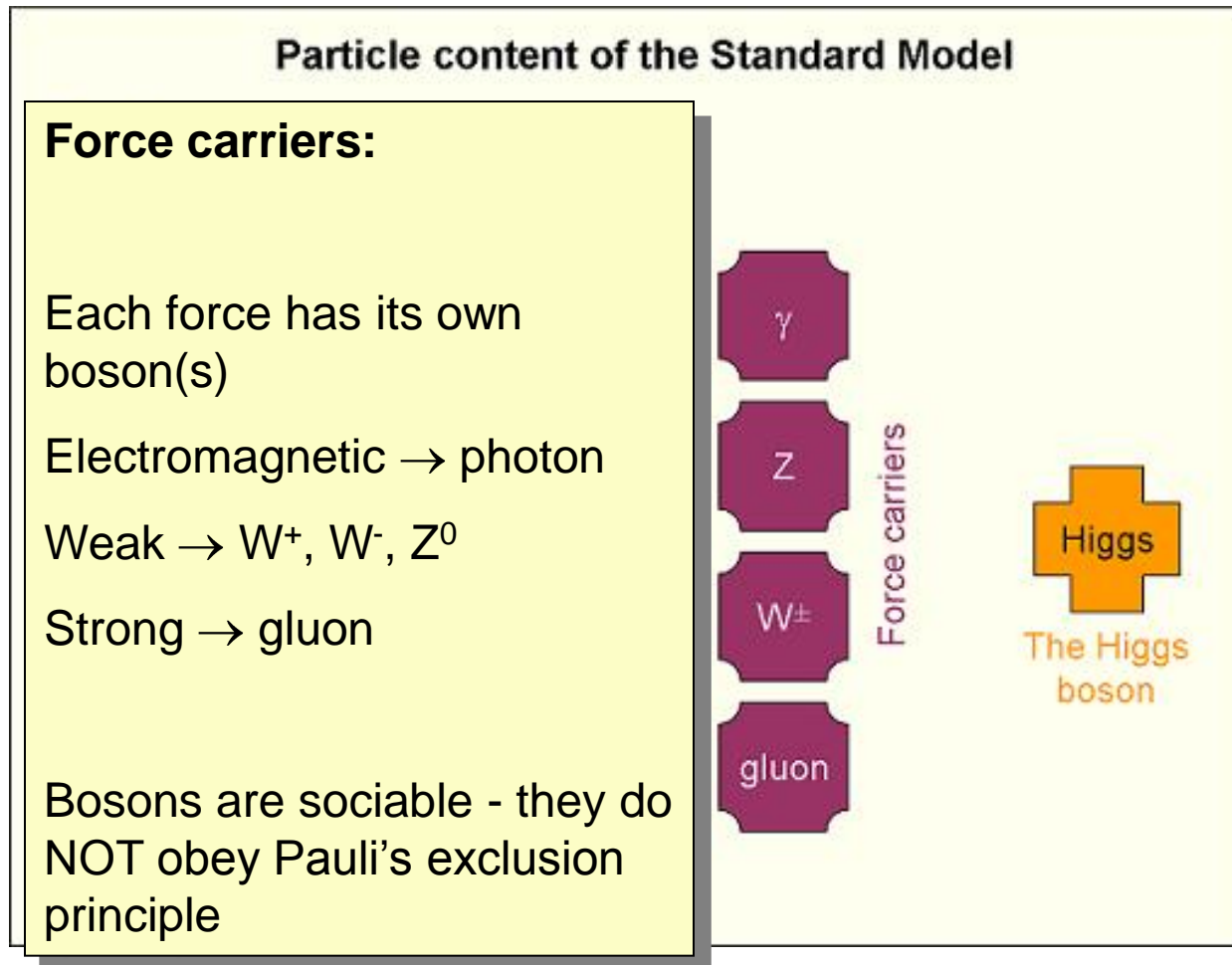




# J1.2: Identify elementary particles



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**Particle content of the Standard Model**

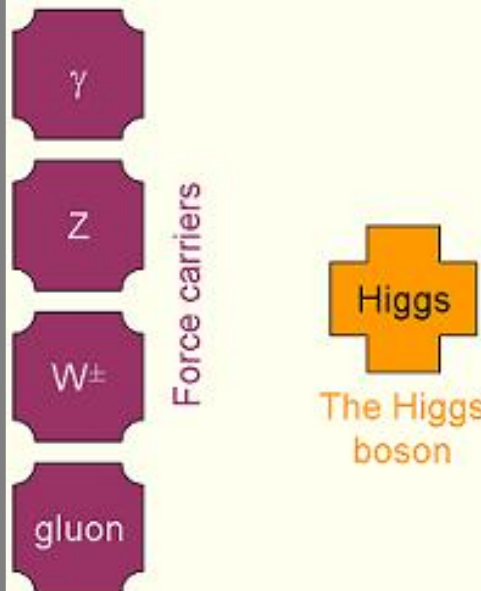
**Force carriers:**

What about gravity?

Einstein's General Theory of Relativity is our best explanation of gravity to date.

It is a classical field theory which does not fit into the standard model (of quantum field theories)

This is a BIG problem!



The diagram shows four purple, pill-shaped icons stacked vertically, labeled from top to bottom:  $\gamma$ , Z,  $W^\pm$ , and gluon. To the right of these icons is the vertical text "Force carriers". To the right of the "Force carriers" text is an orange cross-shaped icon labeled "Higgs". Below the "Higgs" icon is the text "The Higgs boson".

# J1.2: Identify elementary particles

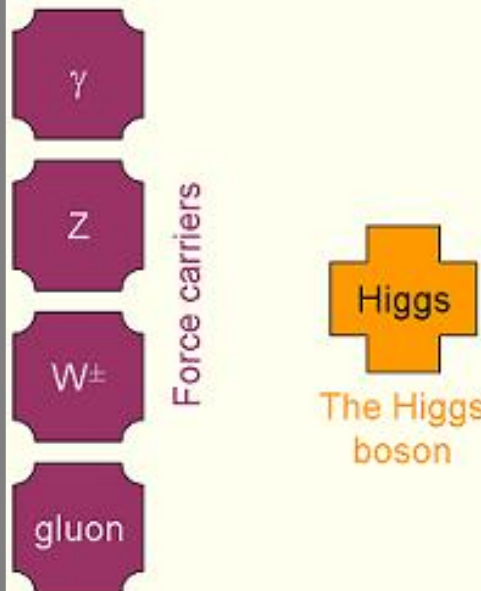
**Particle content of the Standard Model**

**Higgs boson:**

This particle has not yet been discovered!

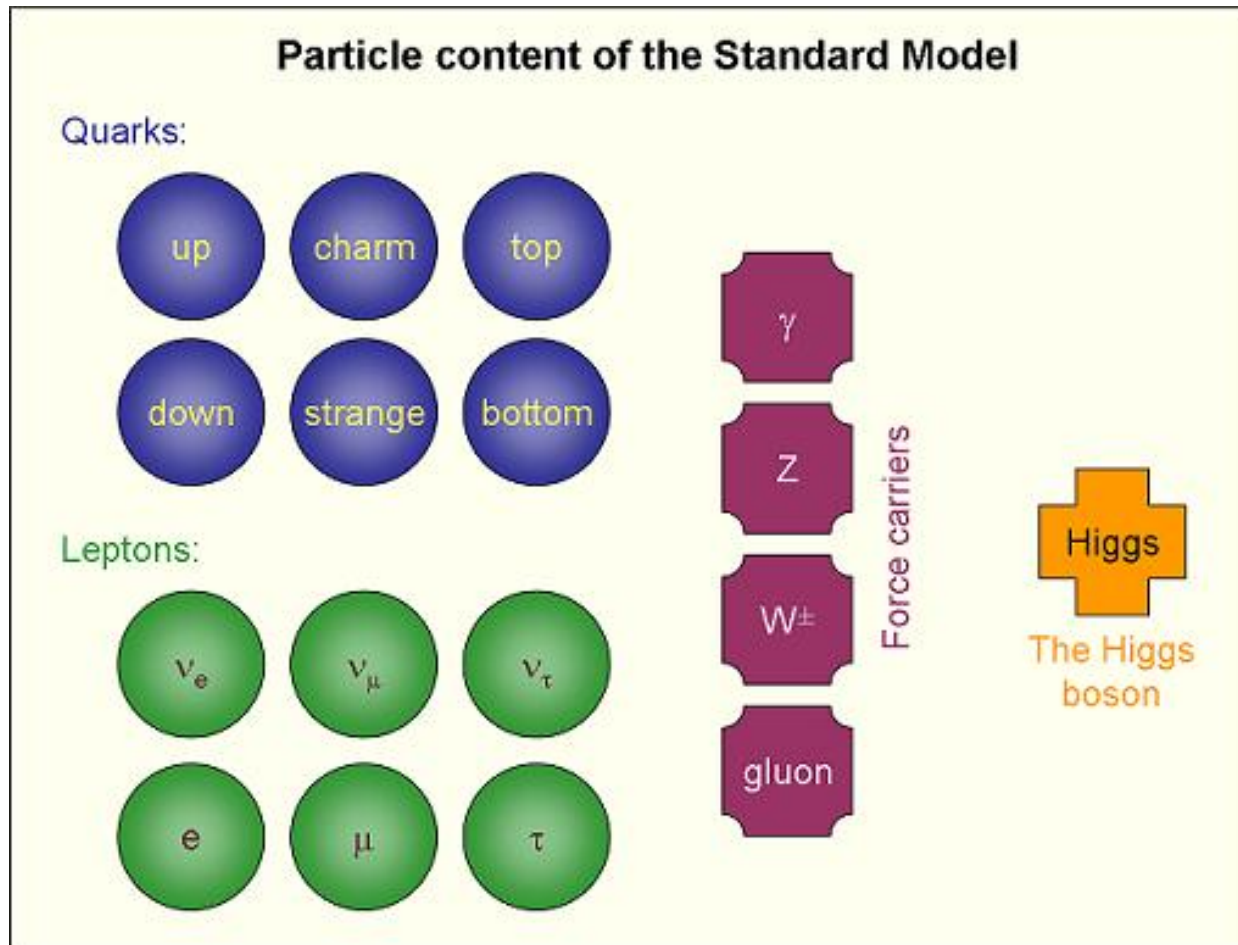
It is hypothesised that other particles acquire their mass by interacting with the Higgs field.

The Higgs boson, if it exists, is a perturbation of the Higgs Field.



The diagram illustrates the force carriers of the Standard Model. On the left, a vertical stack of four purple, rounded rectangular boxes contains the symbols for the force carriers:  $\gamma$ , Z,  $W^\pm$ , and gluon. To the right of this stack, the text "Force carriers" is written vertically. Further to the right, an orange cross-shaped box contains the word "Higgs". Below this box, the text "The Higgs boson" is written in orange.

# J1.2: Identify elementary particles





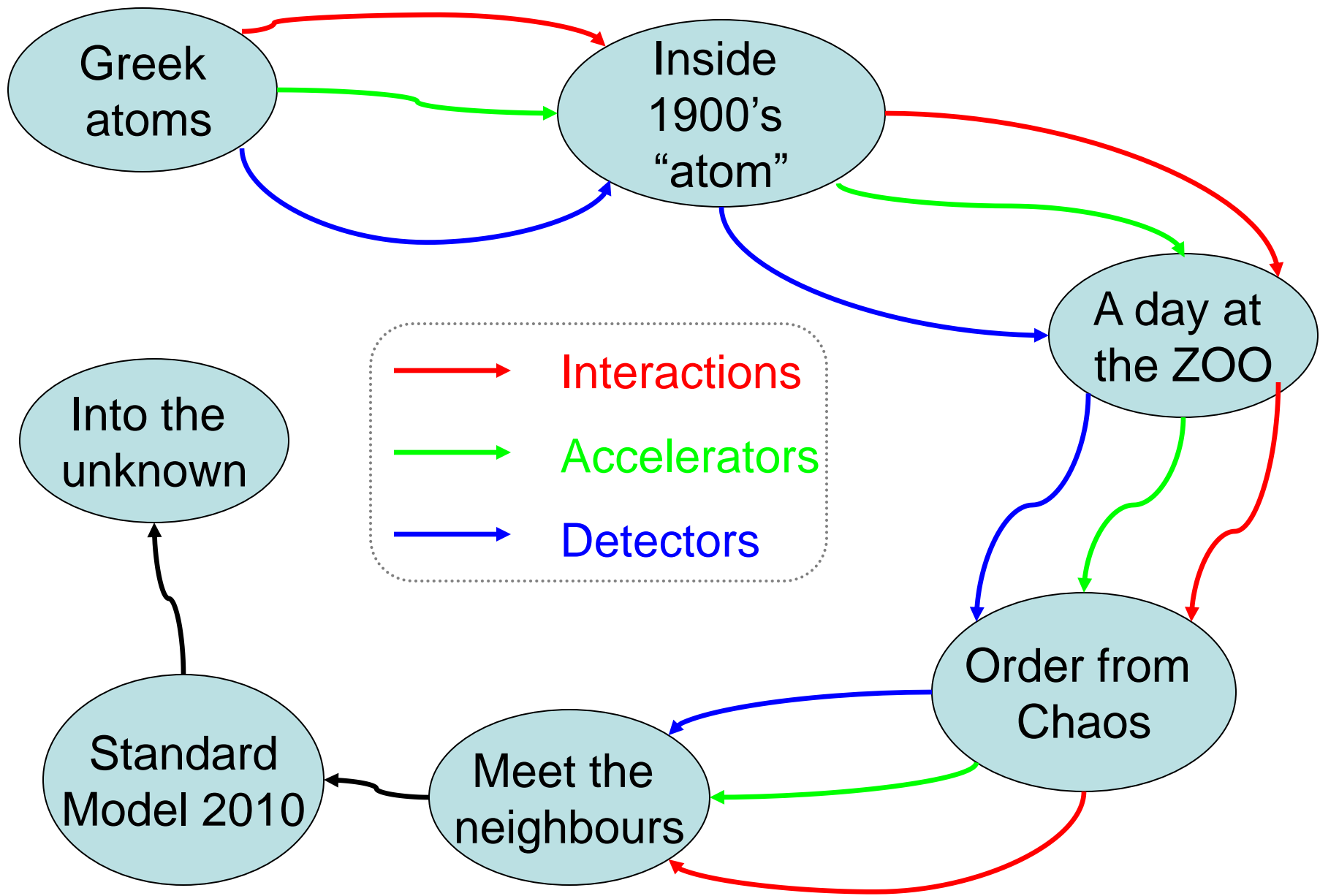
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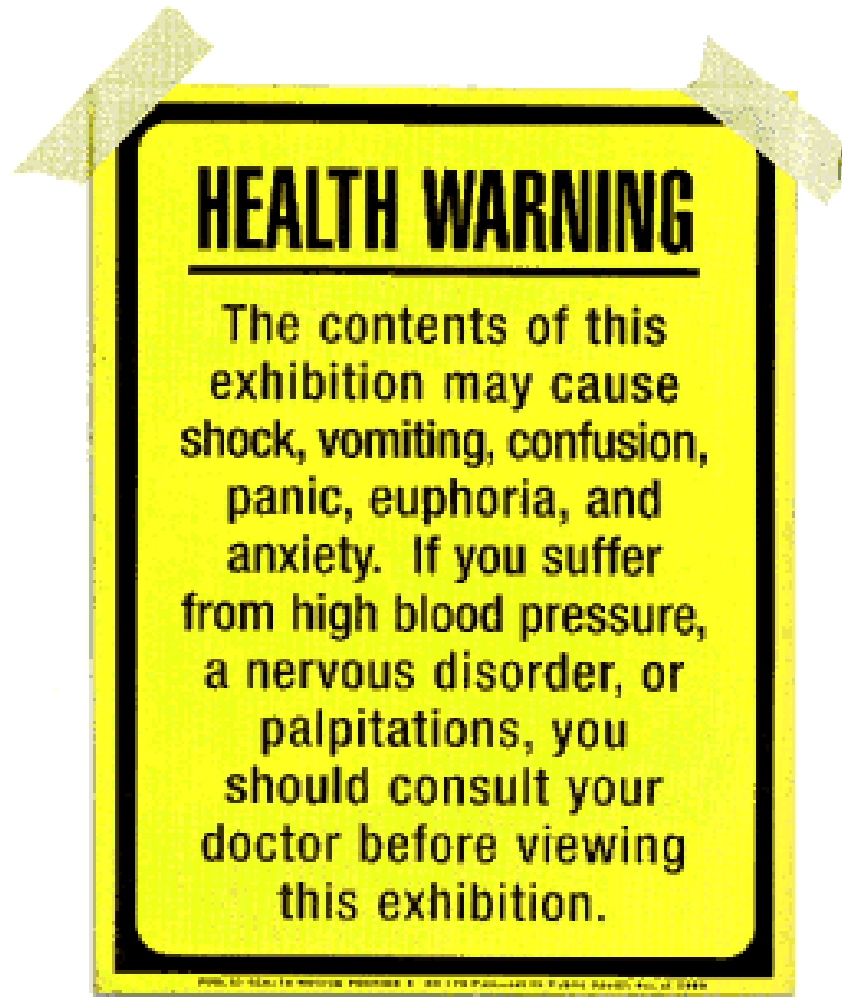




# Aim for this working group

- Brainstorm: generate ideas!
- Find existing resources and edit them into a coherent style / format
- Write new resources (in both directions)
- Produce homework sheets
- Produce ideas for lab assignments

# Health warning!





# Health warning!

- This is the start of an extended project!
- The working group will contribute to the project but **WILL NOT** complete the project in the next 2 weeks
- Very high standards of work are required
- Work will be edited prior to publication

...end

...end

...end