



Diocese of Chester
Science & Religion Forum

Particle Physics:
Thoughts on the
Higgs Particle
and other things

Roger Barlow
Huddersfield University

Plan* for this talk

- I What is particle physics?
- II How does it happen?
- III Why all the fuss about the Higgs?
- IV What about the Big Bang?
- V Science versus Religion?
- VI Personal reflections

* Though calling it a 'plan' is something of an over-statement

Q: What is stuff made of?

A: (John Dalton and others, c 1800)

Everything is made by combining atoms of a few* basic elements.

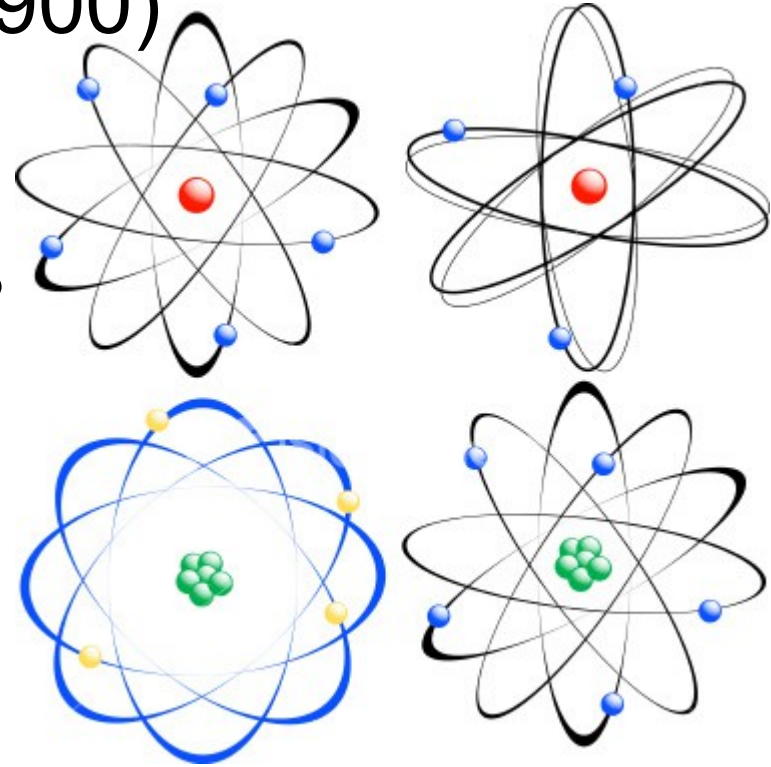


* Well, 92. But that's still small compared to the number of different chemical compounds

Q: What are atoms made of?

A: (Bohr and others, c 1900)

A small, heavy nucleus
surrounded by electrons

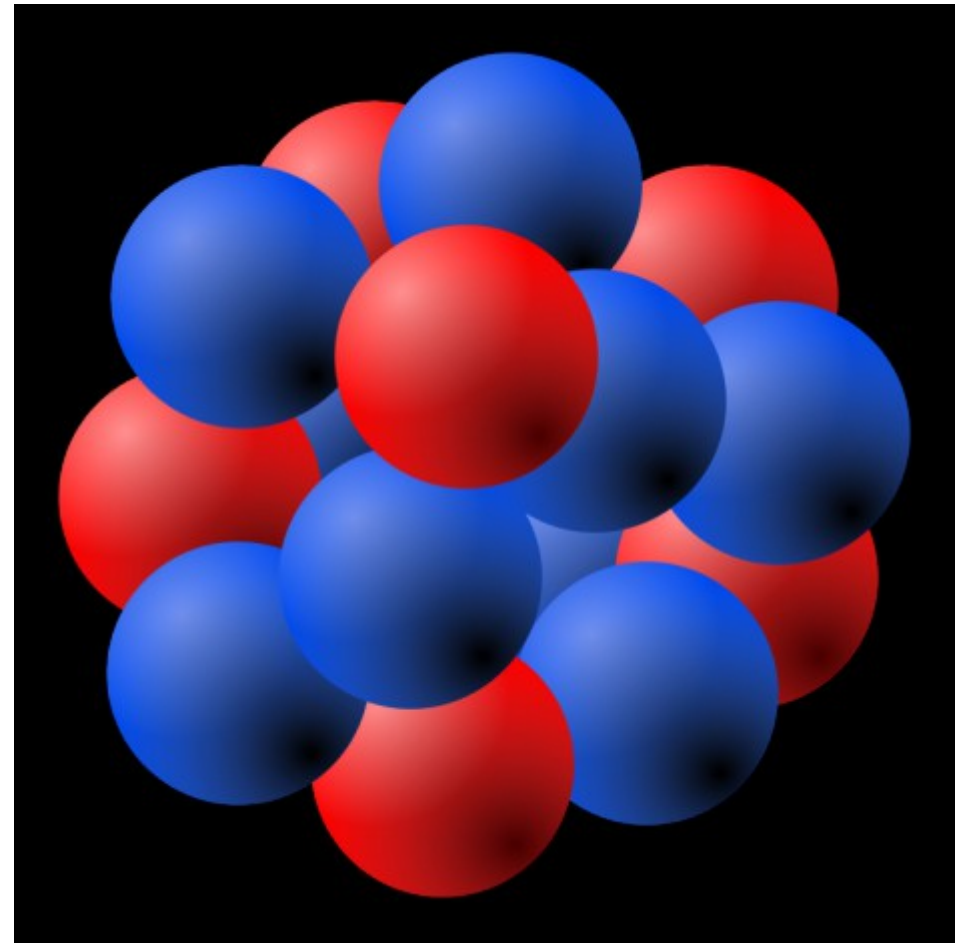


Q: What is the nucleus made of?

A: (Rutherford and others, c 1910)

Protons and neutrons.

The number of protons
in a nucleus
determines which
element it is

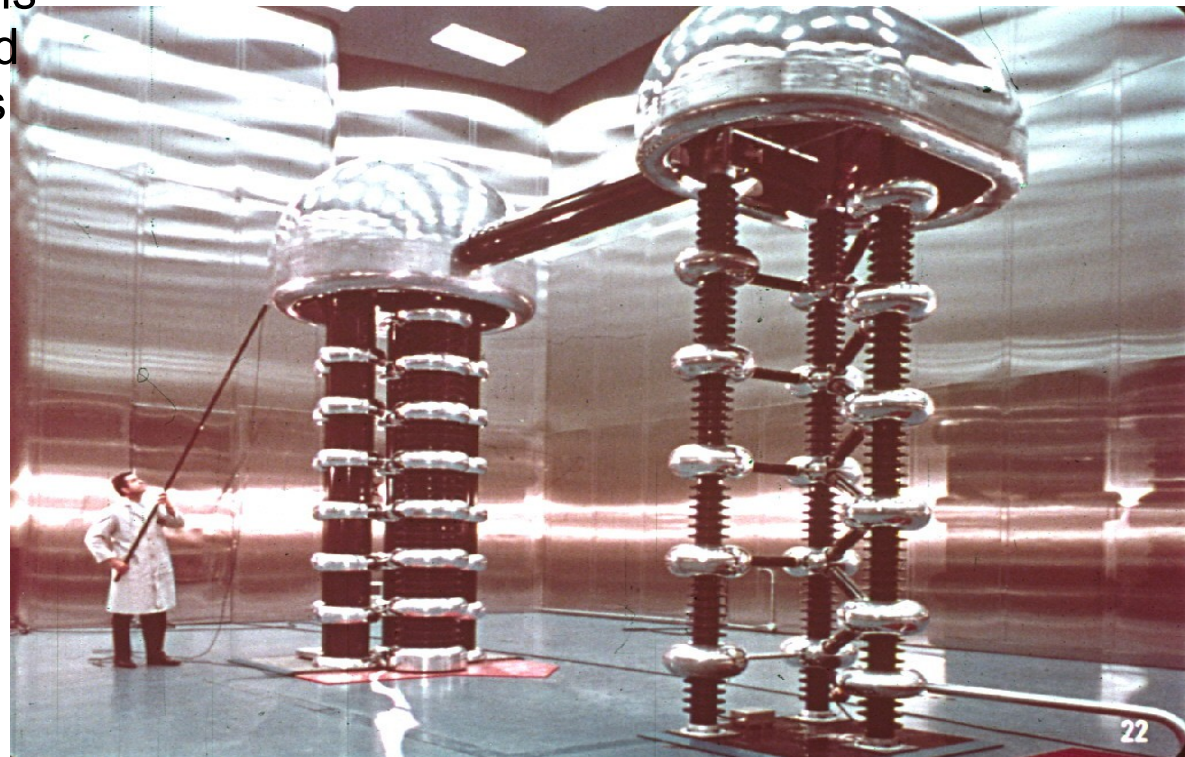


Short breathing space*

1920's physics picture was simple.

Everything is made of 3 elementary particles:
proton, neutron, electron. (And the photon that
carries the electromagnetic force)

Behaviour of electrons and photons
very well understood.. Protons and
neutrons rather less so, but hopes
of progress, thanks to new
accelerators (“atom smashers”)



* Make the most of it!

More particles

Accelerators produced new (unstable) particles

Muon

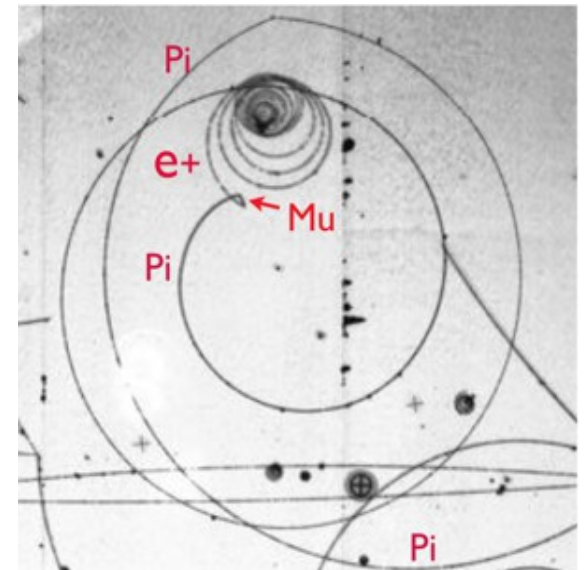
Neutrino

Pion

K and Lambda

Delta, N^* , Sigma,

By the 1960's, well over 100 were known



“Young man, if I could remember all these names, I would have been a biologist.”

Enrico Fermi

Q: What are 'elementary' particles made of?

A: (Gell-Mann and Zweig, 1964)

Quarks. Of which there are 3 species*, called u, d and s (“up”, “down”, “strange”).

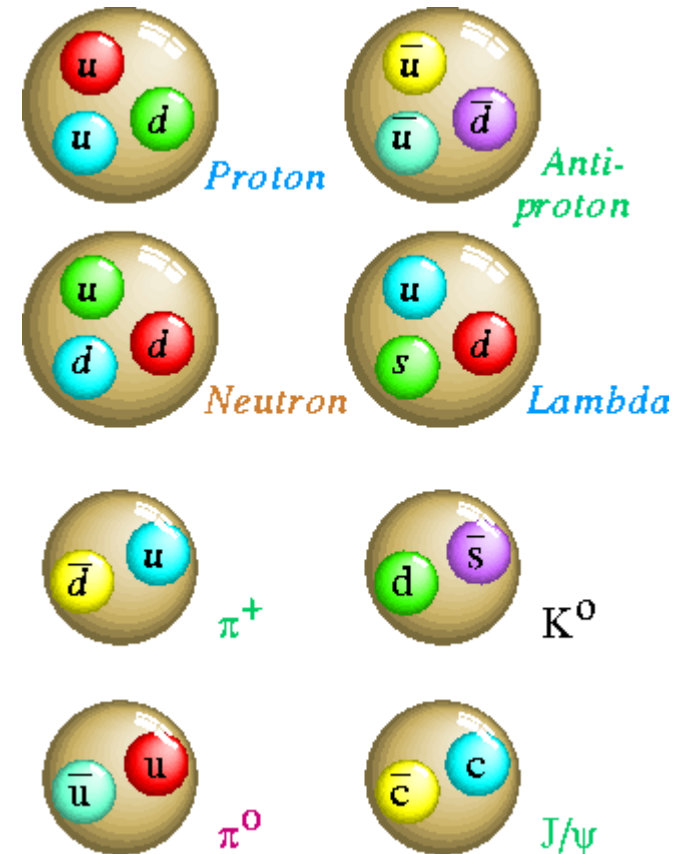
These combine in triplets (proton ,neutron, Delta, Lambda...)

or pairs (pion, kaon...)

Theory had some features that seemed weird at the time. Why twos and threes? Why do you never see a quark on its own?

The electron, muon and neutrino don't fit into this scheme. Nor does the tau (discovered later).

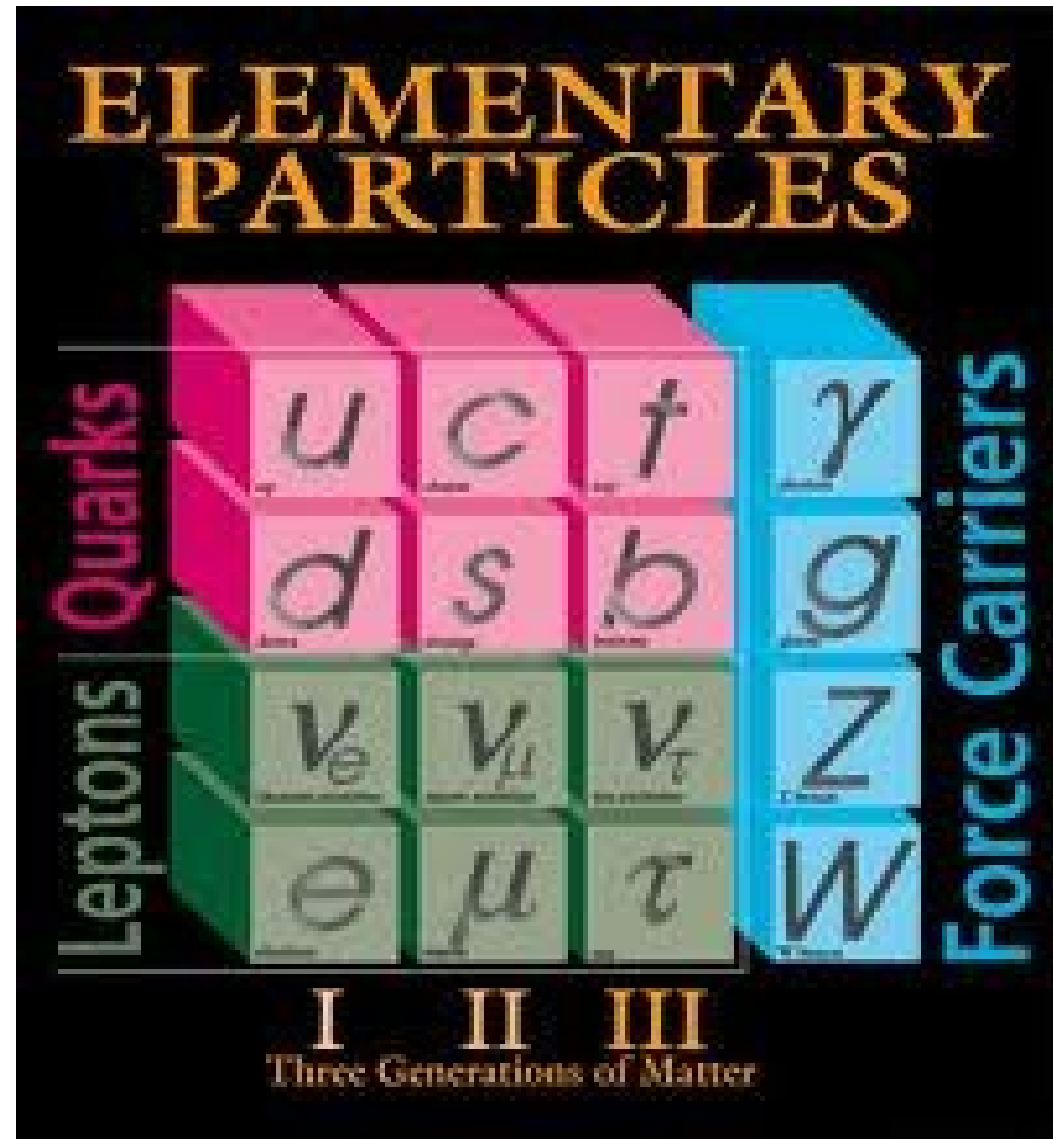
* Now extended to 6 with c,b,t (“charm”, “bottom”, “top”)



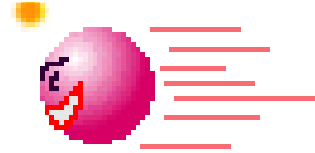
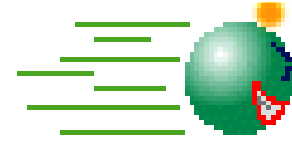
Today's picture

Everything is made out of 12 different elementary particles: also 4 particles that carry forces

The 'Standard Model'



How do we know?



Smash particles together as hard as you can,
and see what comes out.

1: Build big particle accelerator

2: Arrange for particles to collide

3: Surround by detectors

4: Record lots of collisions

5: Interpret the results

Big engineering!
Takes time, money,
effort expertise, lots
of people...

Newscaster: And we'll be saying a big hello to all intelligent life forms everywhere. And to everyone else out there, the secret is to bang the rocks together, guys

From: the Hithchiker's Guide to the Galaxy

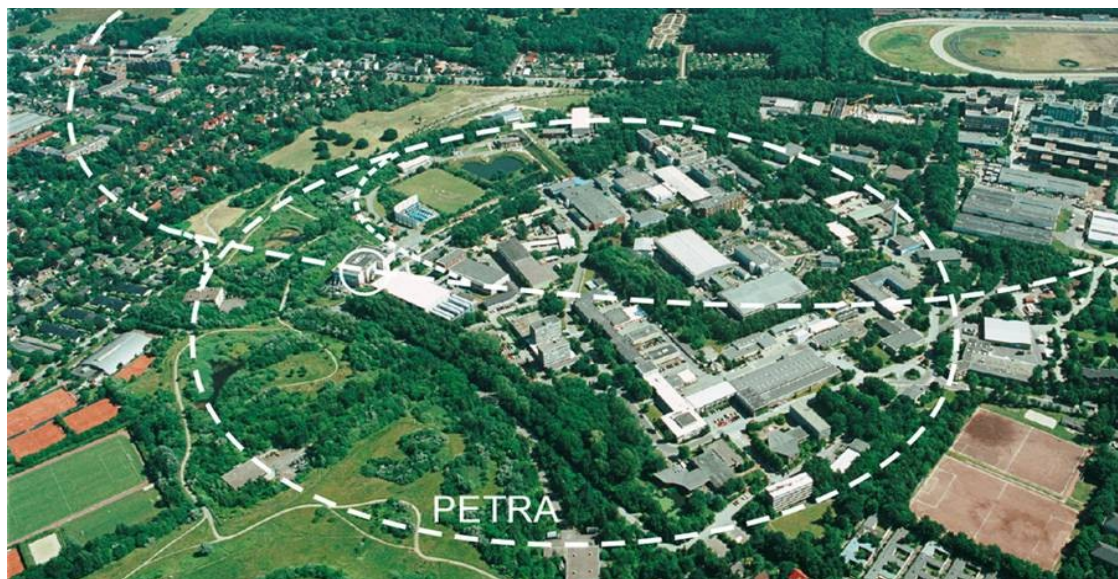
Example: PETRA and TASSO

PETRA (Positron-Elektron-Tandem-Ringbeschleunige-Anlage)
Build and ran in Hamburg in the 1970's and 1980's
Several km round.

Collide positive and negative electrons at 4 points: 4 detectors

One called TASSO

(Twin Arm Spectrometer Solenoid)



I worked on
this as a
post-doc,
with about
70 other
people,
helping
design and
build and run
it and
analyse the
results



LEP and OPAL

LEP (Large Electron Positron) collider
Like PETRA but bigger – 27 km round.
Deep underground, in Geneva, at
CERN.

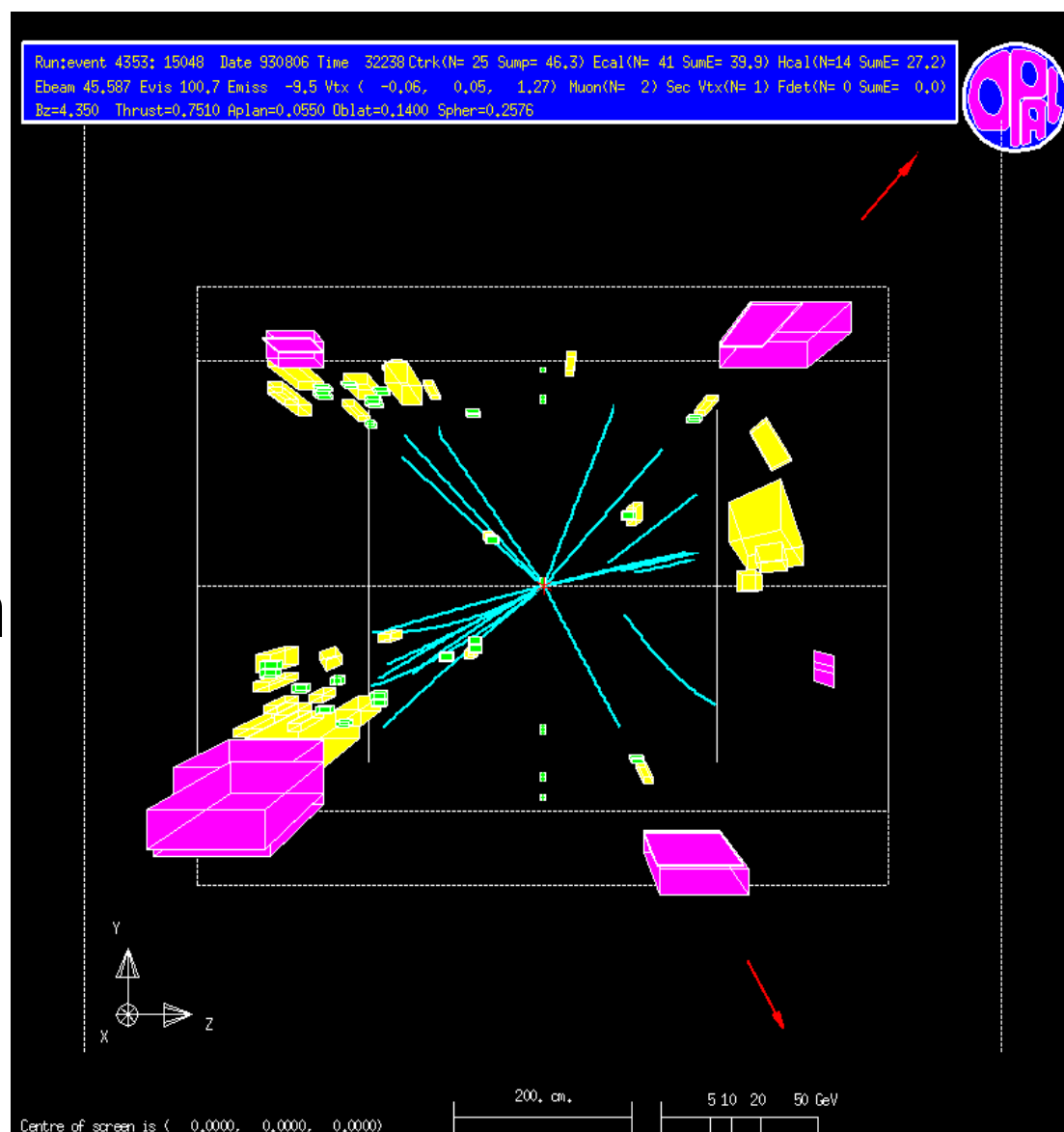
Built 1980's, ran 1990's
4 collision points, 4 detectors, one
called OPAL (Omni-Purpose Apparatus
for LEP)



I worked on this, with about 300
other people. We designed and
built those blue 'muon chambers'
in Manchester. 110 of them, in 4
layers, 10 m long

Results from OPAL

Tracks produced
Event with 2 muons
from a Z particle
discovered earlier,
but detailed
properties tied down
at LEP

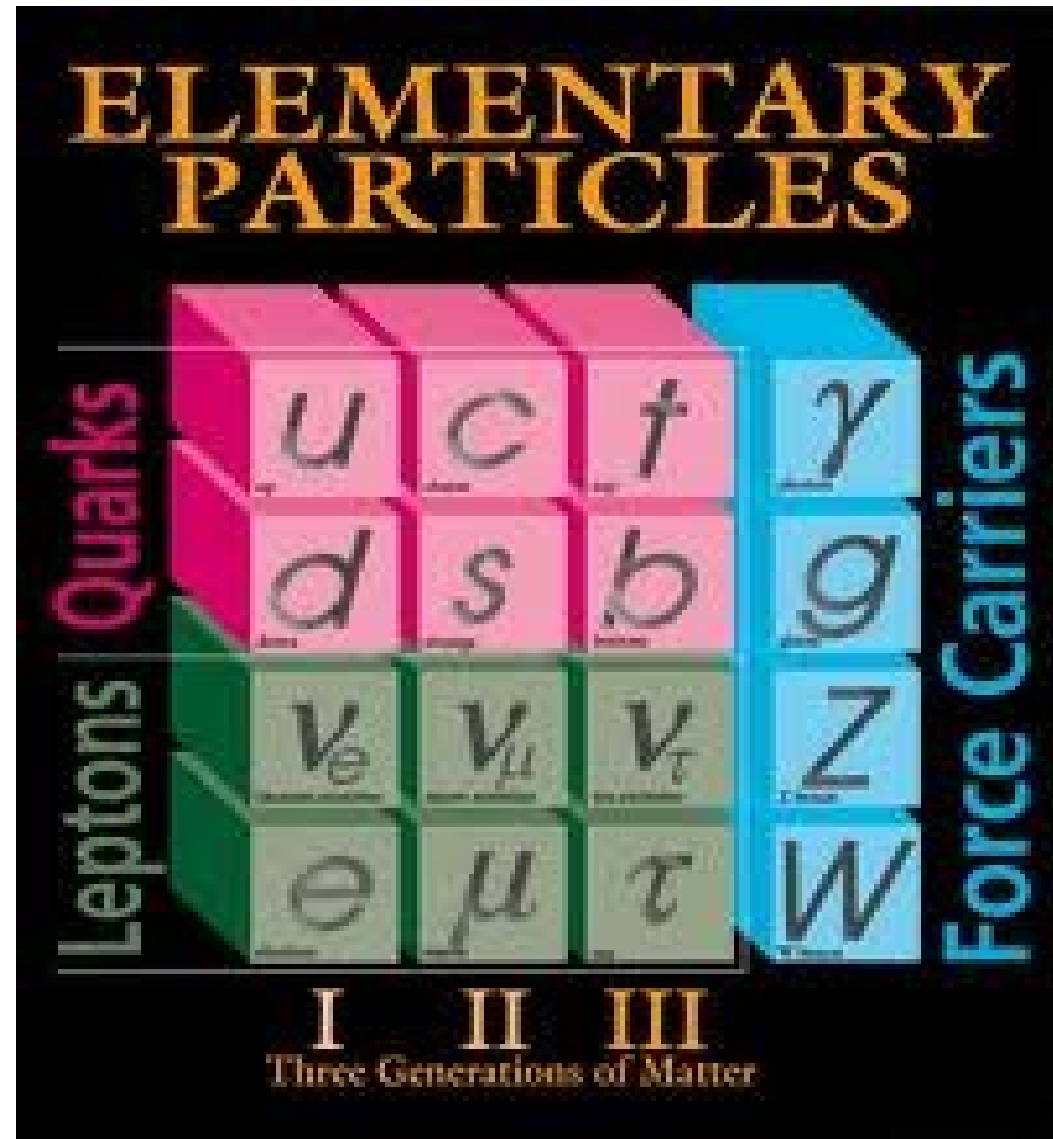


The puzzle (c 1960-2012)

The photon and electromagnetic force well understood.

Theory can be extended to include the gluon.

Extending theory to W and Z only works if they have zero mass. But they don't...

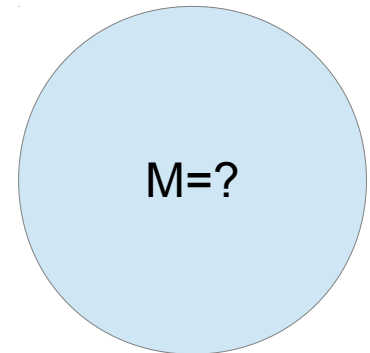


Mass

(This slide is a bit technical. Feel free to ignore it.)

Lots of ways of thinking about 'mass'

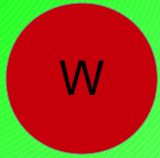
- inertia
- amount of material
- what slows you down
- gravity
- ...



All equivalent in the long run

Useful concept here is through $E=mc^2$

The mass is the energy ($/c^2$) needed to create a particle



Higgs' idea



The Rule is: W and Z have zero mass. But...

Suppose there is some field – call it H

OK, fair enough

Suppose the W and Z are affected by that field
(but gluon and photon are not)

Could be

Suppose that, even in empty space, that field is
not zero but has some value

That's seriously weird

Then to make a W or Z you need to provide
energy for its H -field interaction. Looks just like a
mass but evades the rule...

Analogy: is it helpful? You tell me...

The church had many visitors. They
were asked for donations, but the
treasurer was never satisfied.

He proposed an entry fee: £1 per visitor.

But the bishop forbade it.

So the treasurer flooded the church with
ultrabright spotlights, so the visitors
could see nothing without special
sunglasses

Which he rented to them, at £1 a pair.

If Higgs is right and this field exists,, you must be able to do something with it. Make waves
in it. Which means particles.

Hunting the Higgs

The theory was nice, it made lots of successful predictions about particles and their properties

But it did not predict the mass of the Higgs particle itself – just that it had to exist.

We searched for it at PETRA and didn't find it.

We searched for it at LEP and didn't find it.

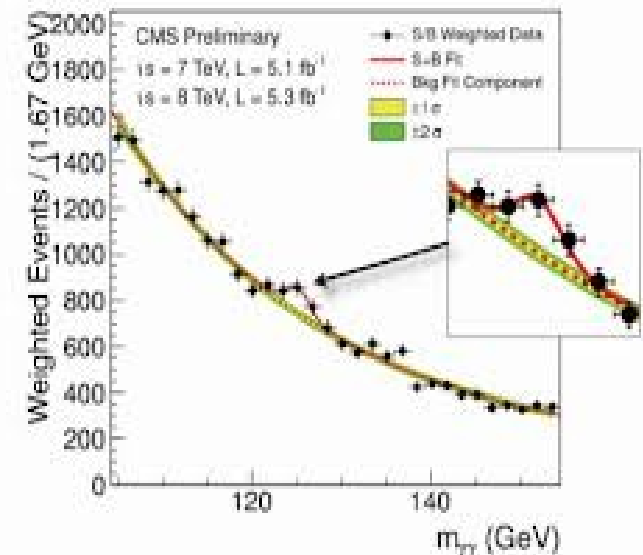
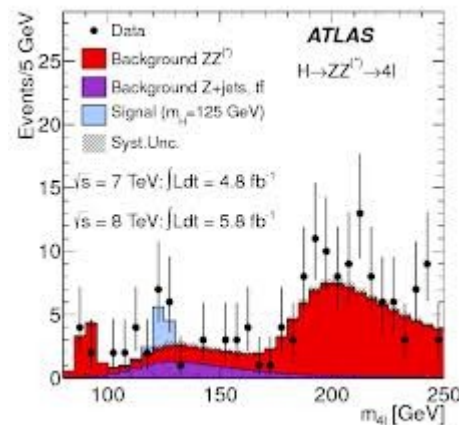
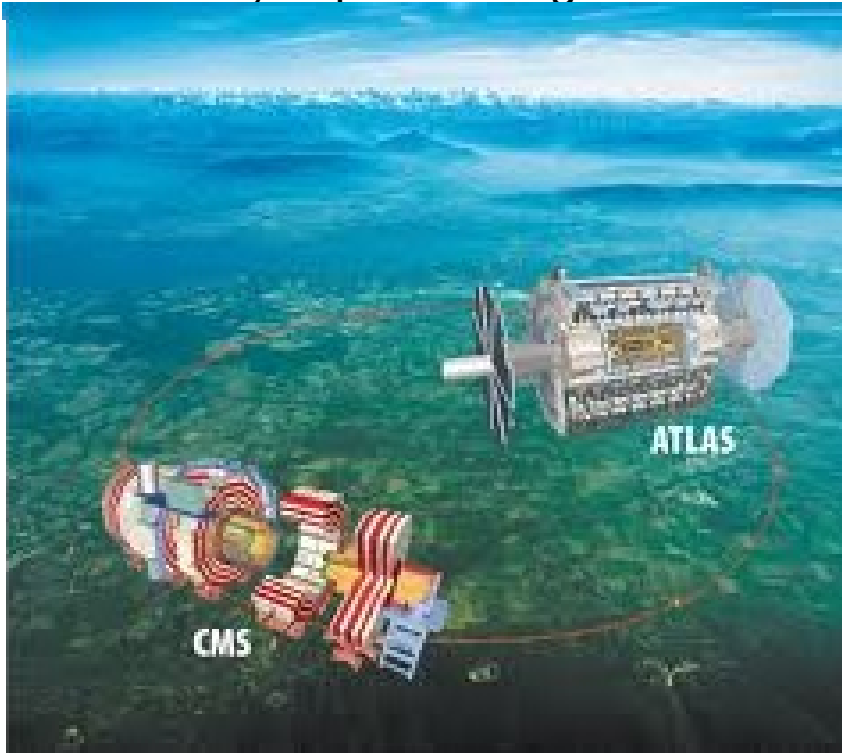
(Lots of publications. And statistical expertise in interpreting null results.)

At this point (early nineties) the LHC and its experiments were being planned.

I decided not to join them, but to work on an experiment called BaBar which was studying the differences between matter and antimatter. After that I joined the LHCb experiment which is at the LHC but not looking for the Higgs particle.

Discovery! 2012

Two – entirely separate - big detectors called ATLAS and CMS



The God particle?

- REALLY silly name
- appeared in a 'popular' science book – though the author (Ledermann) blames his publisher
- justification (slim!) is that without it – or, rather, without the Higgs field, the universe would have no variety and be very boring. Particles would have the same properties, mostly zeroes.
- please don't use the name. It annoys (1) Peter Higgs (2) every other particle physicist (3) Probably God too.

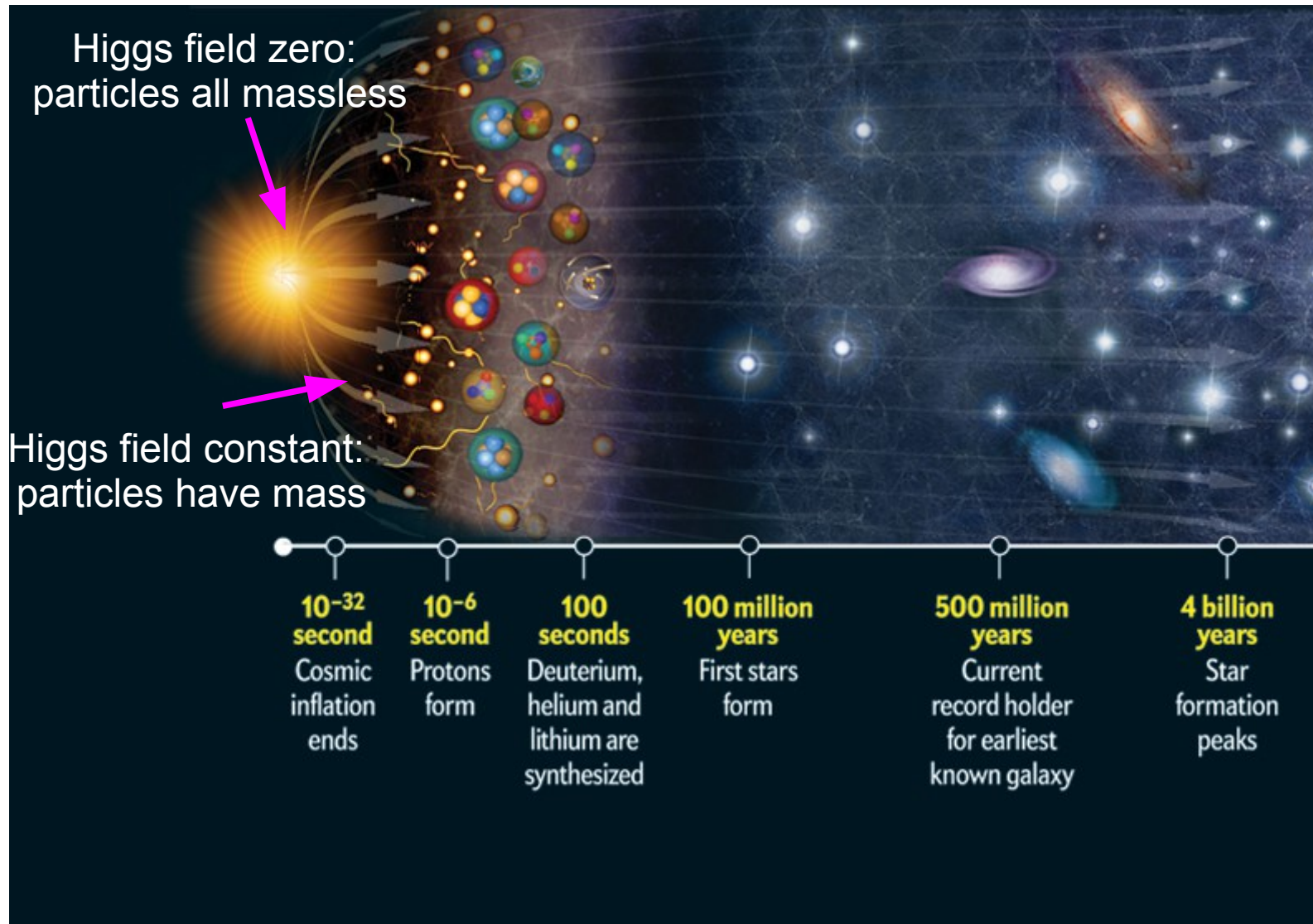
The Higgs is quite sensational enough. Final piece of jigsaw puzzle of particle physics – and it fits perfectly.

Enormous intellectual achievement!

Also the process of acquiring its non-zero value was crucial in the early stages of the Big Bang.

Very small and very large scale studies meet

The Big Bang



Information from Cosmic Microwave Background –
get someone from Jodrell Bank at a future meeting

But Genesis says....

How old is the universe?

13.5 Billion years

6000 years

- Cosmology
- Geology
- Evolution

- The authority* of the bible

* Scientists do not acknowledge authority other than logic and experiment

Genesis is wrong: so what?

The bible is not a physics textbook*.

It does not (like the Koran) claim to be infallible. Not written by God, but about God.

Yes, scripture 'containeth all things necessary to salvation' – and also a lot of other stuff

Why are we even having this debate? It was fought out in the 19th century and the creationists lost. I blame the US religious right...

Defending an indefensible position is a gift to Dawkins & other evangelical atheists

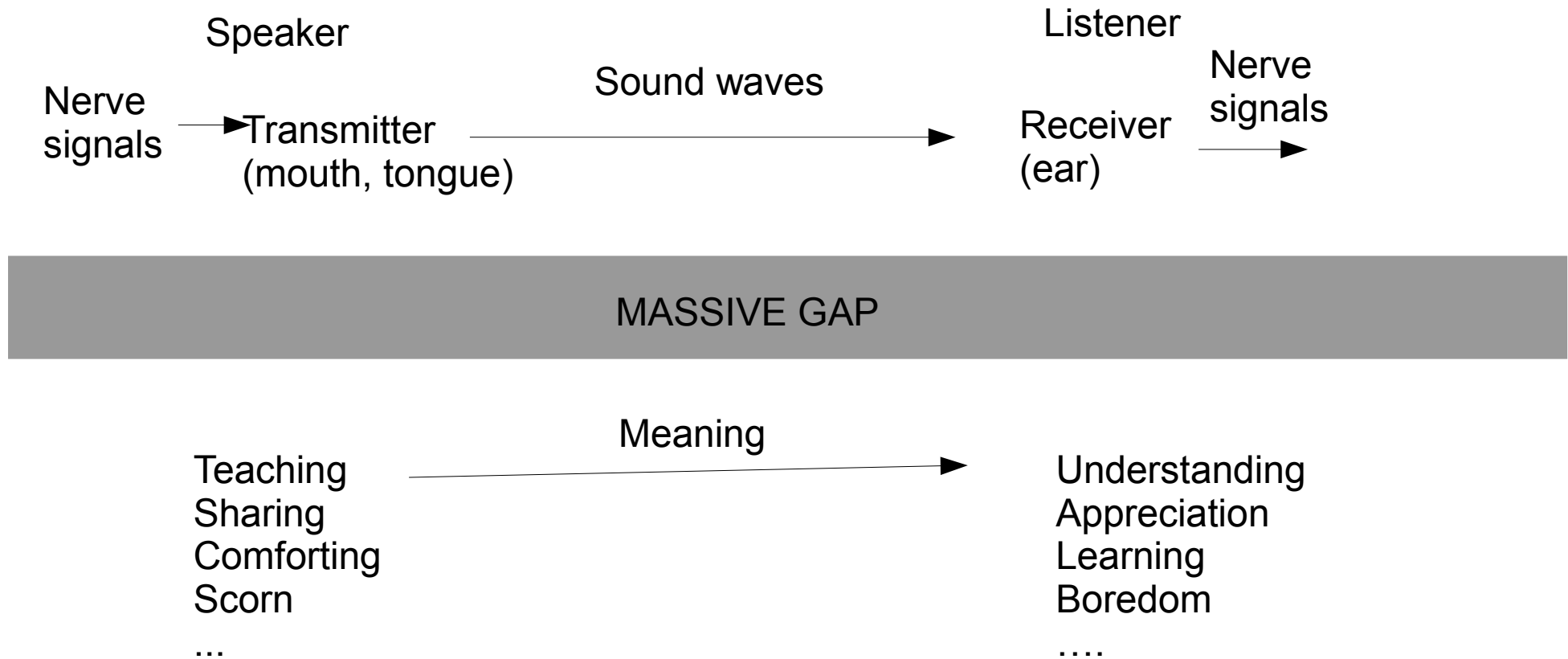
* Actually, if I had to explain the Big Bang, evolution etc using the language and concepts of 600 BC, I'd come up with something not unlike Genesis ,

But...

Things happen according to natural law. Which we now understand pretty well.

What scope does that leave for any divine action? Let alone creation, miracles, etc.

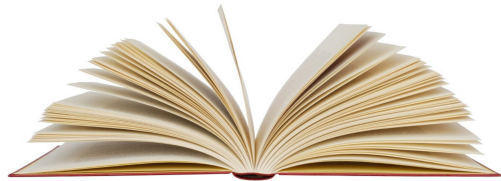
Things that happen can be 'explained' in different modes



'Human' concepts with no meaning/relevance in a purely material description

Other examples

Book



Produced by a printer
Written by an author
Which is the 'creator'?

Computer



Circuits display pixels
with no knowledge of
content

Chess



Moving a piece is
governed by the laws of
physics
and also by the laws of
chess

In the realm of human thoughts, feelings, relationships, science has nothing to say.
(At least: not at a primary level.)

If our existence has meaning, then there is something outside science, and a God, who created the world like an author does a book, and acts through people, is possible and natural.

The 'ground of our being', as Tillich and others put it

And, for me, it's the only way the world makes sense.

Where does that get us?

Science will not provide a proof, or disproof, of God's existence.

Do we learn about God by studying his creation? (The “book of nature”.) Probably not. We're not smart enough.

But the sweep of the universe, from very small to very large, is just staggering. It runs on basic laws which are beautifully elegant.



“The heavens declare the glory of God; the
skies proclaim the works of his hands”

Psalm 19