ATLAS:

An introduction to particle detectors

What do you know about particle physics and cern?

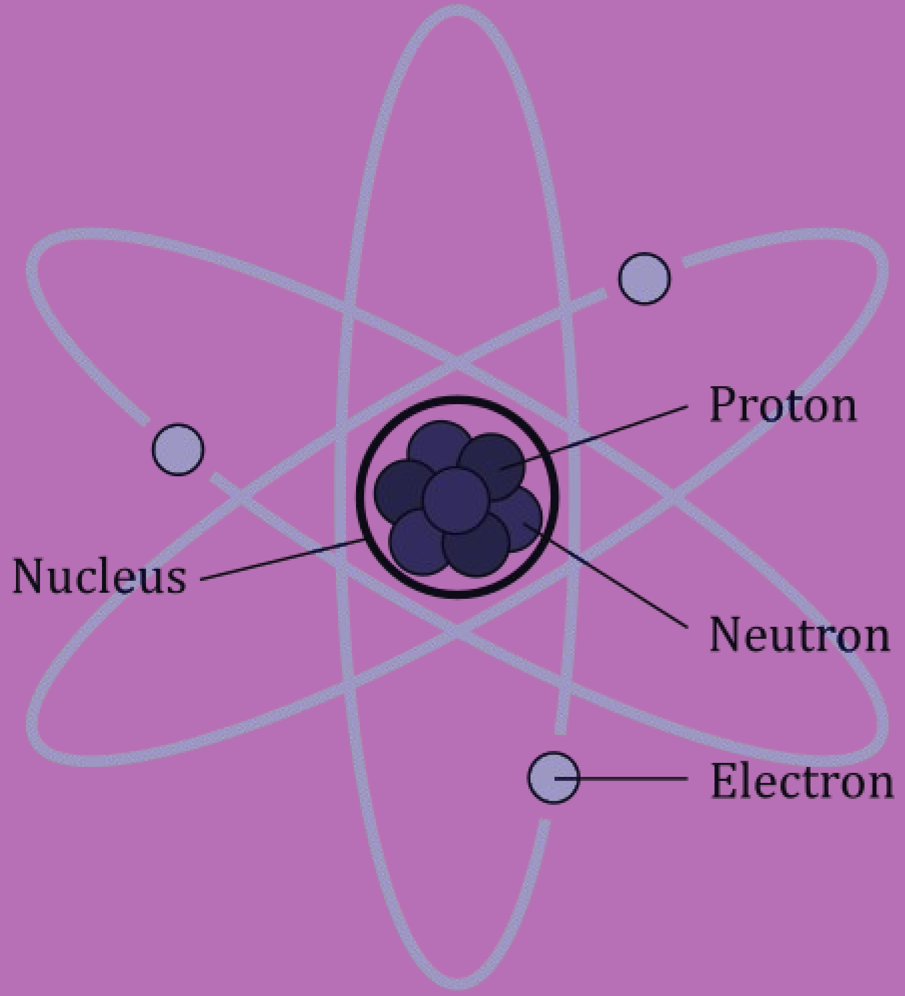
Conspiracy theories welcome!

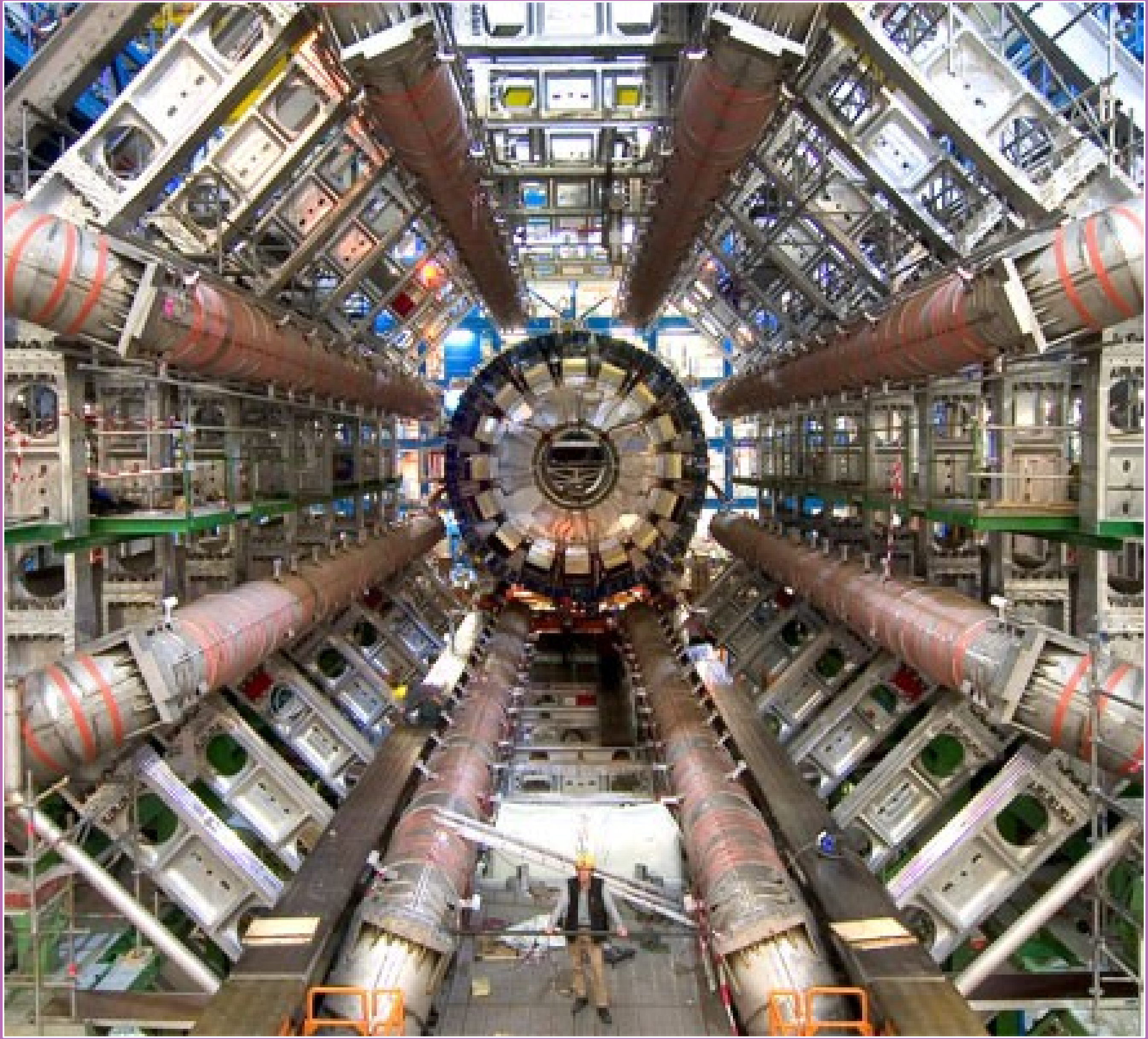
PARTICLE PHYSICS IS WEIRD

- Particle physics studies the stuff that makes up atoms, think protons, neutrons and electrons.

- The world of particle physics has its own special rules since its governed by quantum rules.

- On this small scale the universe is governed by probabilities, meaning you can do the exact same thing multiple times and different





CERN AND THE LARGE HADRON COLLIDER

The LHC speeds up particles to near the speed of light and smashes them into each other.

By smashing them together we can destroy them, creating and observing the particles that make them up.

THE BASICS

So there's a few things we need before we get started:

1. Stress balls
2. Understanding of Units
3. Einstein's Relativity
4. An understanding of Energy

Special units - THE ELECTRON VOLT

1 electron volt (eV) is the energy it takes for an electron to move across 1 volt.

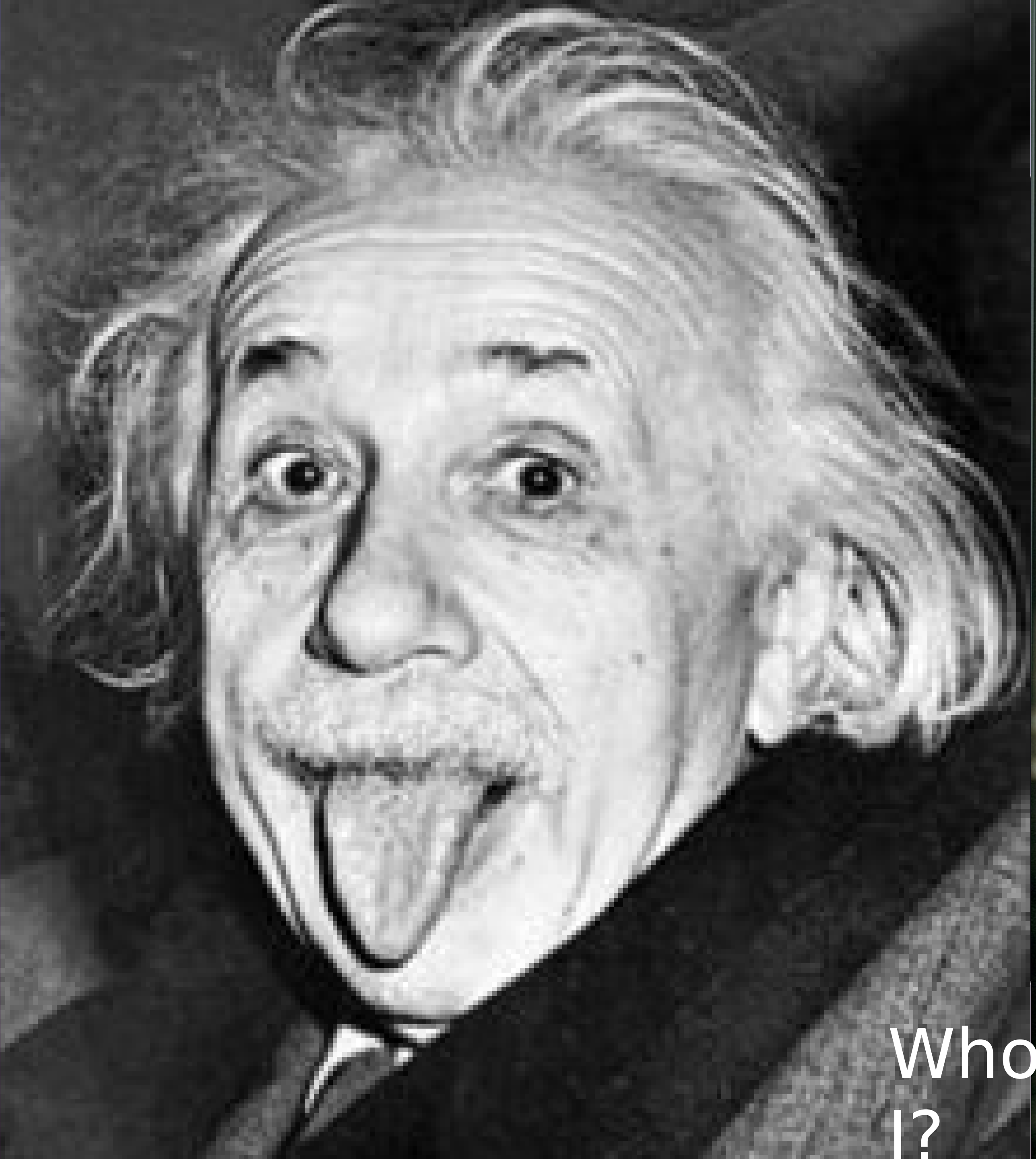
This is 0.00000000000000000016

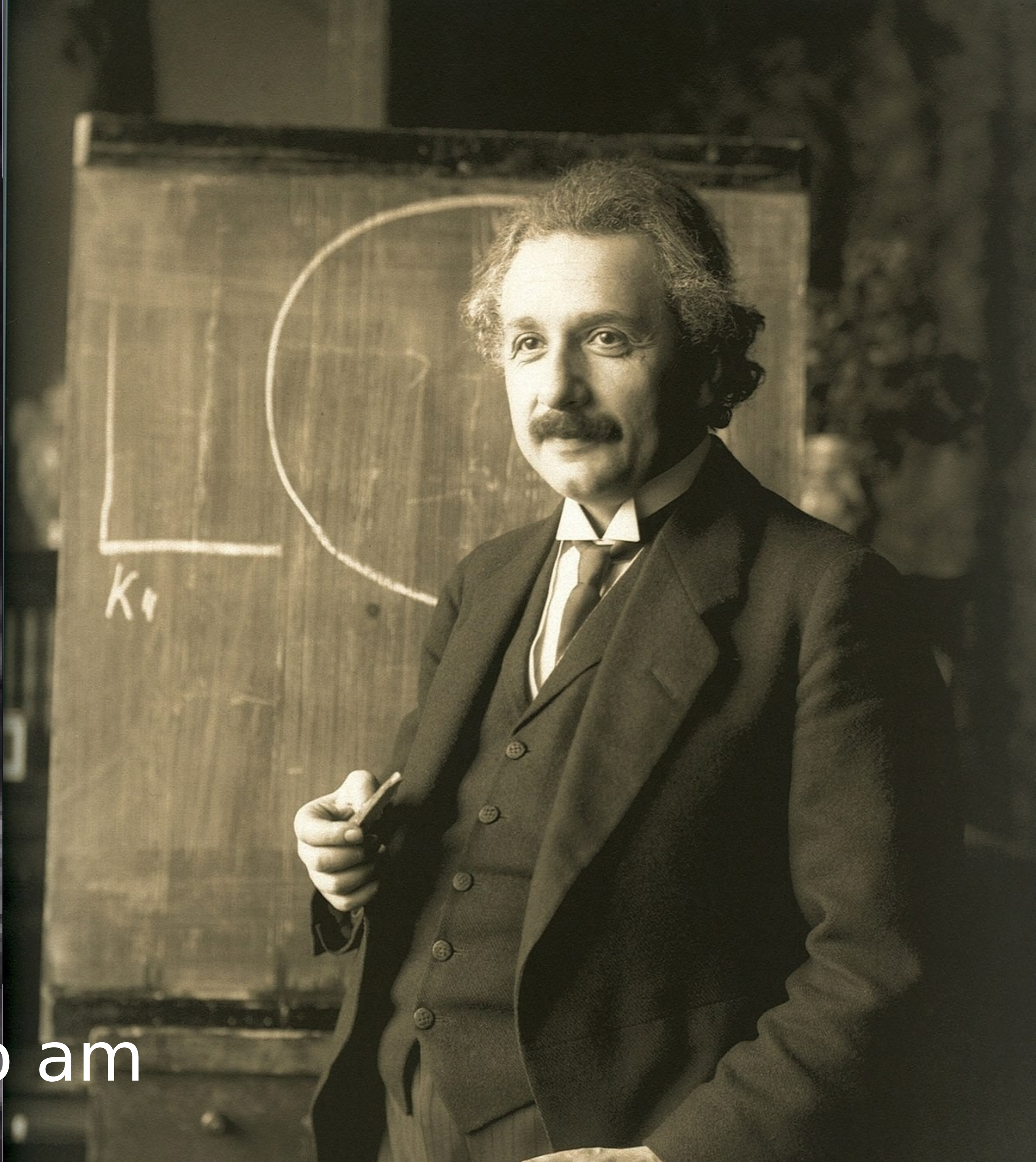
WHY USE IT?

1eV = 0.00000000000000000016 Joules.

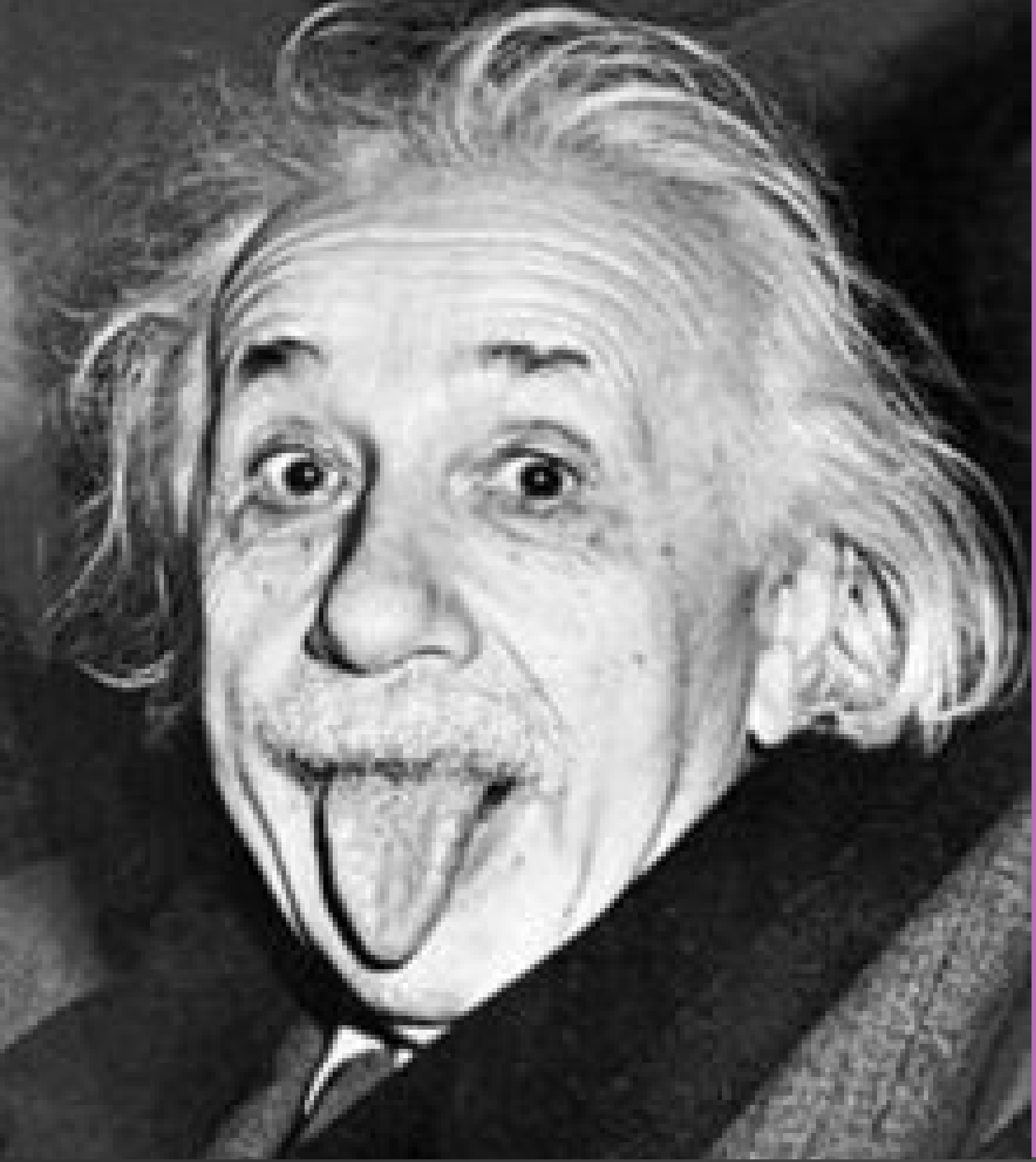
Which is so long I copy and pasted it rather than typing it…

Scientists use eV as they provide more convenient numbers for calculations.

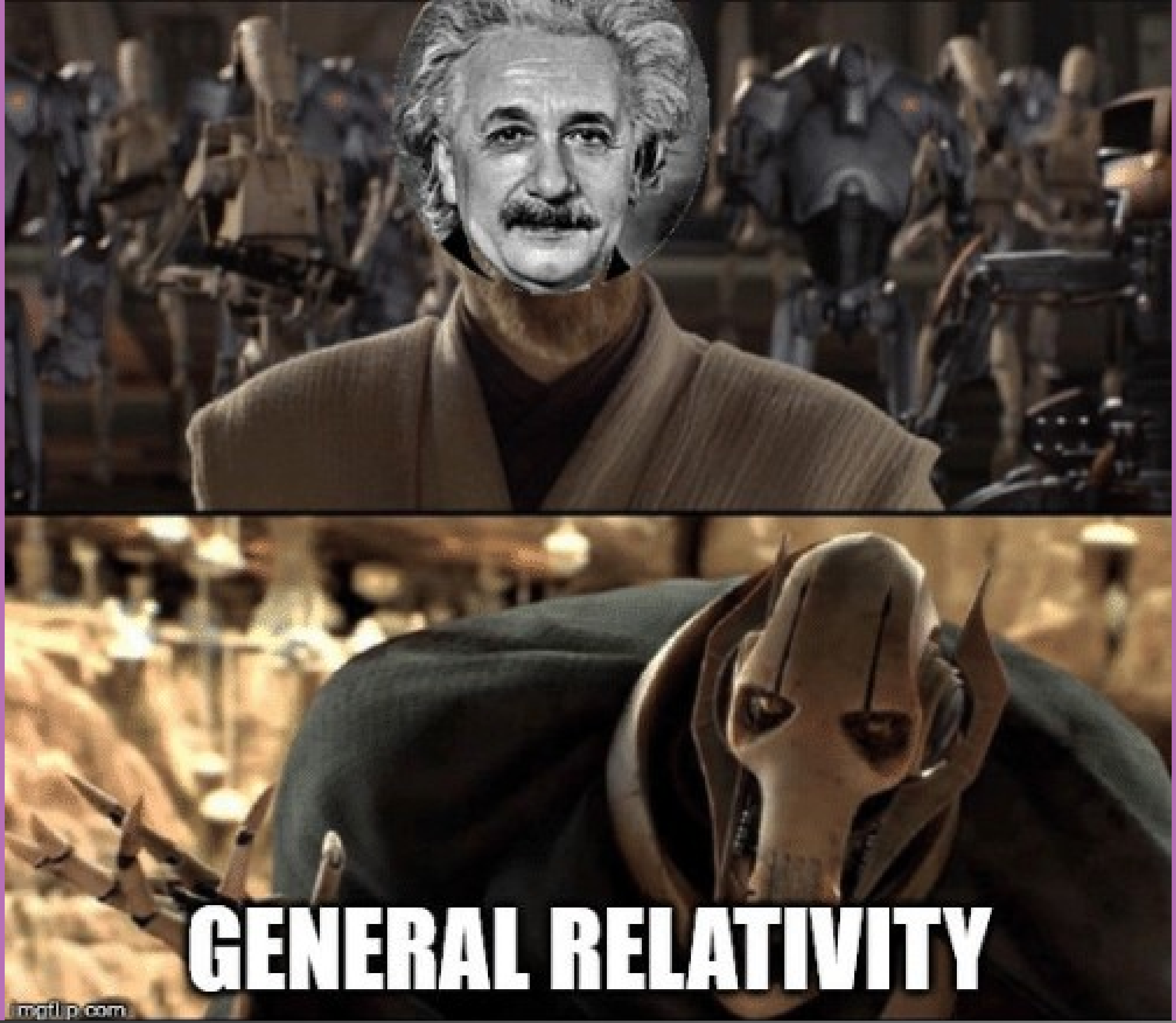


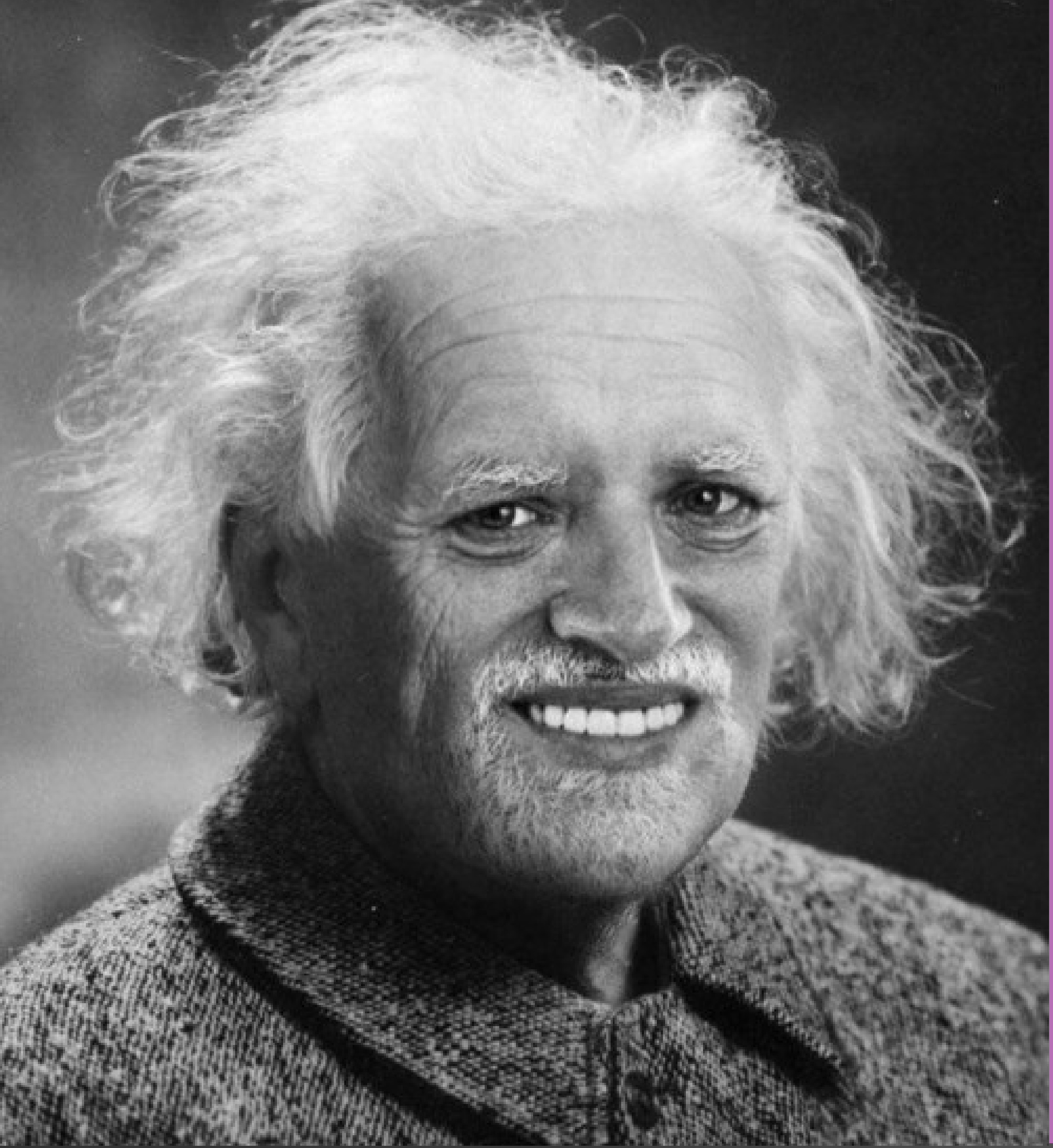


Who am I?



WHY IS EINSTEIN FAMOUS?


GENERAL RELATIVITY
imgflip.com



GENERAL RELATIVITY

Particles at the LHC are speed up to near light speed.

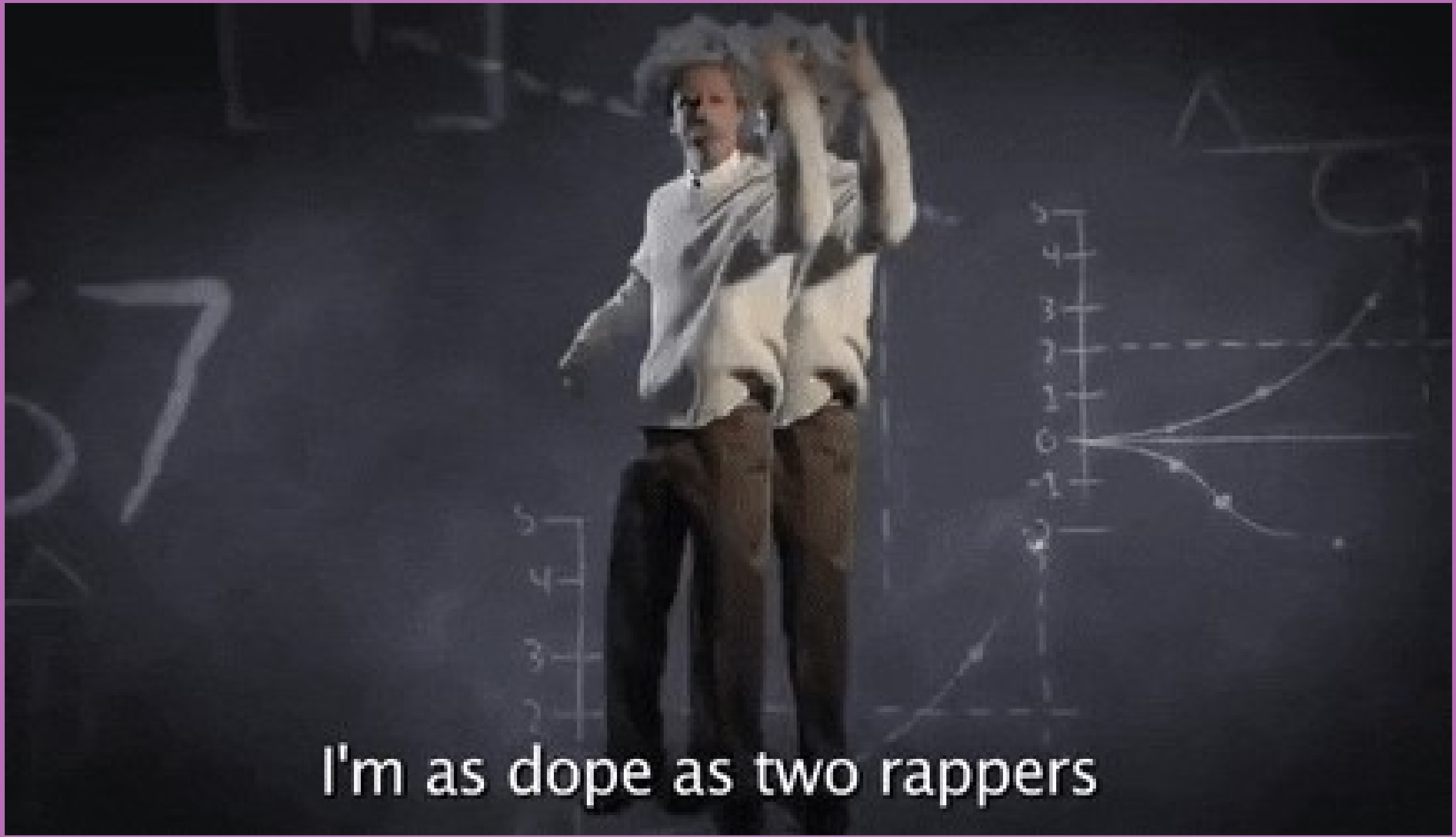
At these speeds the usual laws of physics can’t describe what happens.

As a result we have Relativistic equations, these account for the effects of being near light speed.

(Google the equations if you want to see the final form of

WHAT IS EINSTEIN'S ENERGY EQUATION?

HANDS UP IF YOU THINK :



$$E = m \times C^2$$

Thats known as the mass energy equivalence equation.

This a simplified version of the actual equation and is only true for still objects.

Through this equation, the rest mass is:

$$m = \frac{E}{C^2}$$

$$m = \frac{J}{(ms^{-1})^2} = Kg$$

THE ACTUAL ENERGY EQUATION

$$E^2 = P^2 \times C^2 + m^2 \times C^4$$

E = Energy (J)

P = momentum (kg m/s) = mass x velocity

m = mass (kg)

C = speed of light = 300,000,000 m/s

$$E^2 = \underbrace{P^2 \times C^2}_{\text{Energy from movement}} + \overbrace{m^2 \times C^4}^{\text{Energy due to existence}}$$

Pair up and get a calculator!

An electron has a mass of 9.1×10^{-31} kg what is this in MeV?

a) 16 Gev

b) 3ev

c) 0.51Mev

Remember:

$$m = \frac{E}{C^2}$$

$$C = 2.99 \times 10^8 ms^{-1}$$

$$1ev = 1.6 \times 10^{-19} J$$

c) 0.51Mev

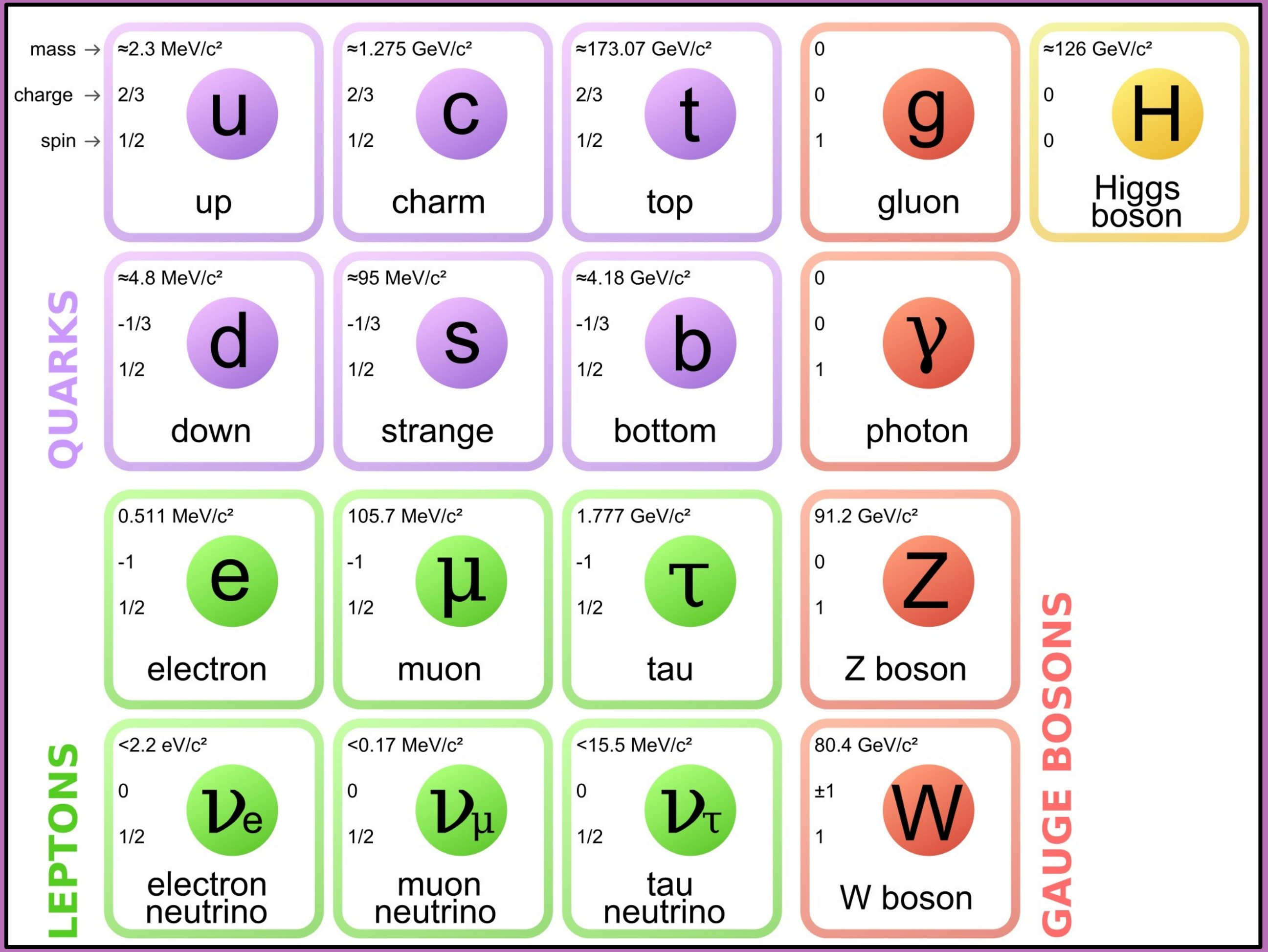
$$E = m \times C^2$$

$$m \times C^2 = 9.1 \times 10^{-31} \times (2.99 \times 10^{8})^2$$

$$= 8.14 \times 10^{-14} J$$

$$
\begin{aligned}
E &= 8.14 \times 10^{-14} / 1.6 \times 10^{-19} \\
&= 508,468\,\mathrm{eV} \\
&= 0.51\,\mathrm{MeV}
\end{aligned}
$$

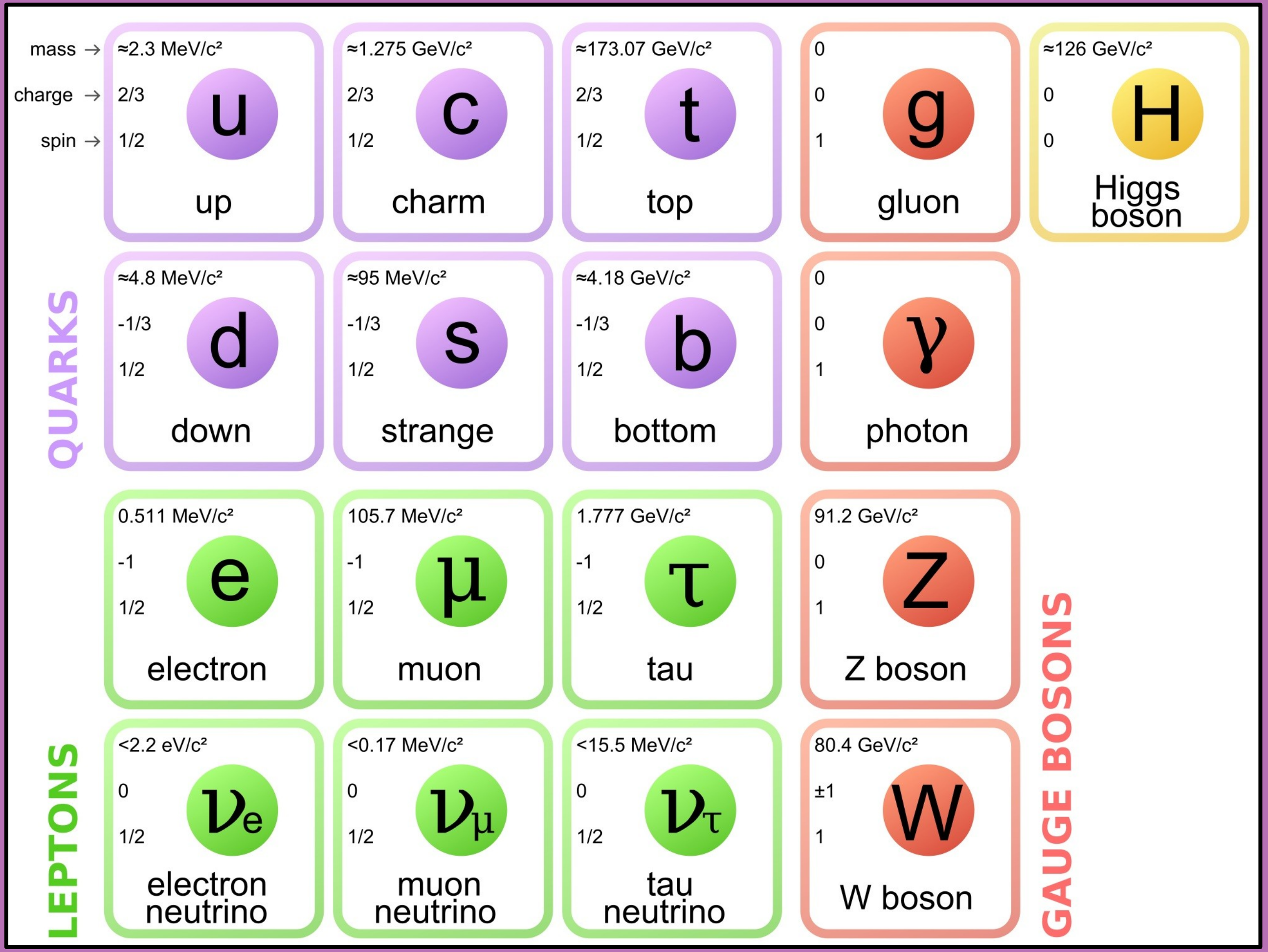
The Standard model:



This is the current model.

Every time a new particle is found its added and the table is adjusted.

The Standard model:



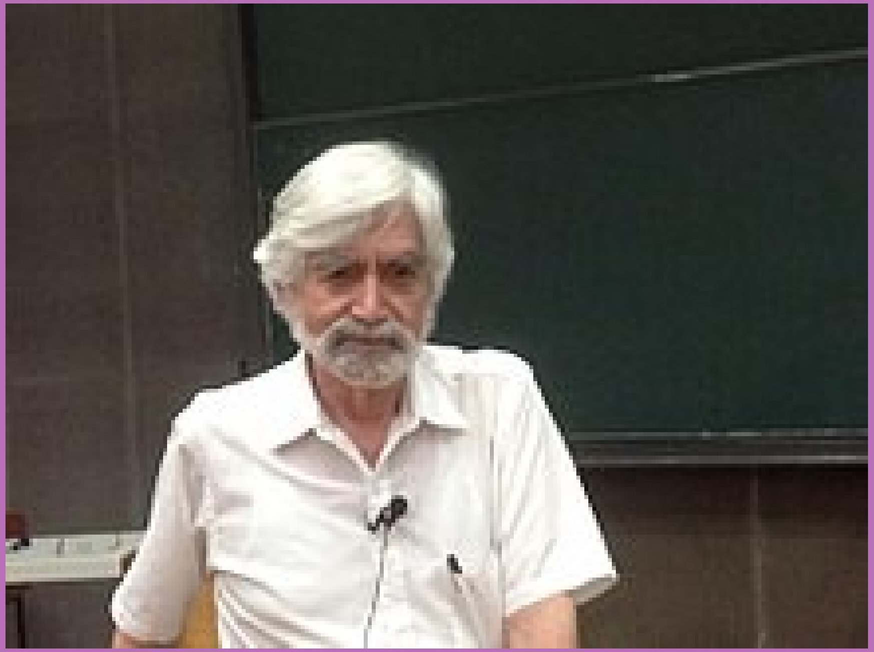
Ok things get weird;

Quark and leptons are referred to by their ‘flavour’

And Bosons carry out the forces.

In 1964 Murray Gell-mann and George Zweig came up with the foundation of the standard model

Murray



George

They defined flavour of subatomic particles, it's a way of distinguishing the particles, dont worry about it.

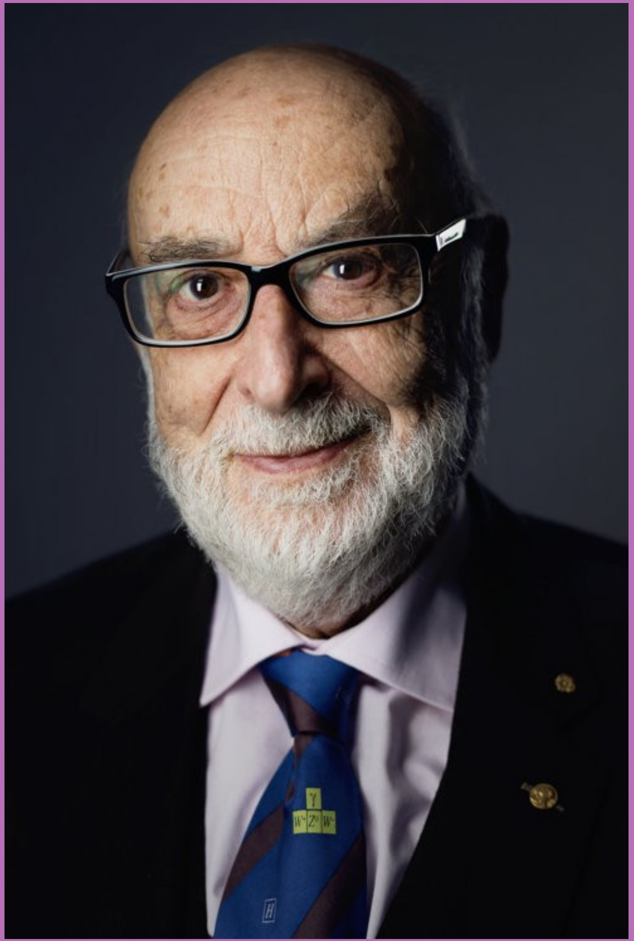
Cern and the Higgs

40 years after the prediction of the higgs, it hadn't been found.

In quantum mechanics the lack of gravity was unexplained, with the higgs being a possible solution.

This lead to Cern and the LHC, their goal to detect

Francois Englert and Peter Higgs theorised the Higgs boson in 1964, they won a nobel prize for it in 2013.



Francois

Peter

The Higgs boson has a mass of approximately 125 GeV, what is this in kg?

a) 1.99×10^{-23} kg

b) 2.23×10^{-25} kg

c) 6.35×10^{3} kg

Remember: $1ev = 1.6 \times 10^{-19} J$

$$C = 2.99 \times 10^{8} ms^{-1}$$

b) 2.23×10^{-25} kg

$$m = 125\ \text{GeV}$$

$$m = \frac{E}{C^2}$$

$$= 125\text{GeV} \times 10^9 \times 1.6 \times 10^{-19} \Big/ \left(2.99 \times 10^8\right)^2$$

$$= 2.23 \times 10^{-25}\ \text{kg}$$

How did they find it?

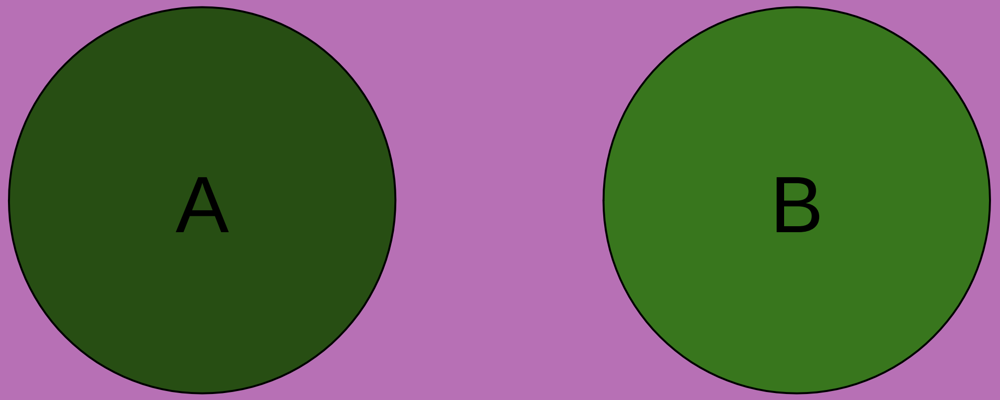
- When particles come into existence they follow conservation laws.

- The total energy and charge of the decaying particles has to be the same as the total of the new particles and their charge have to be same.

- When the LHC smashes particles together we can see groups of particles produced based on these rules.

Different Decays:

Let's use a simple example, colour. Two coloured particles A and B

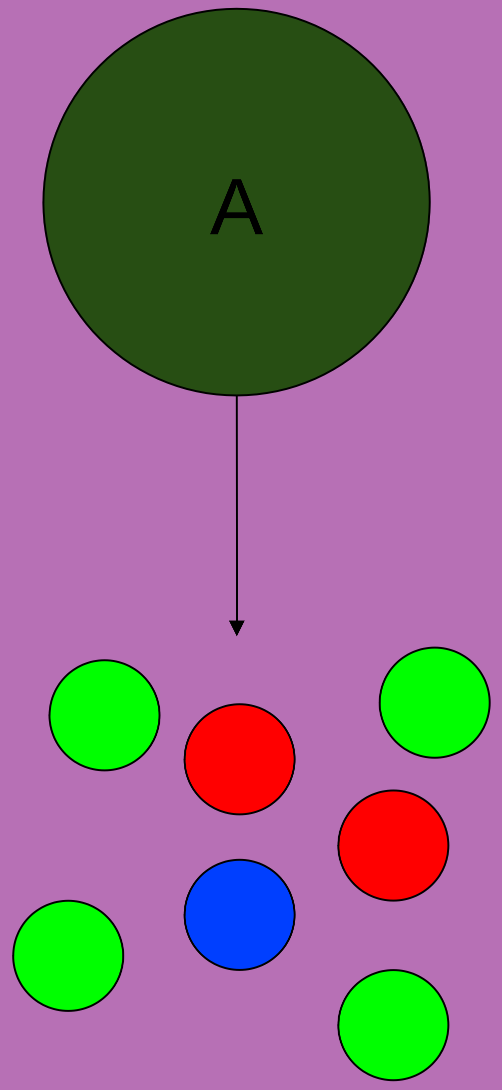


A:

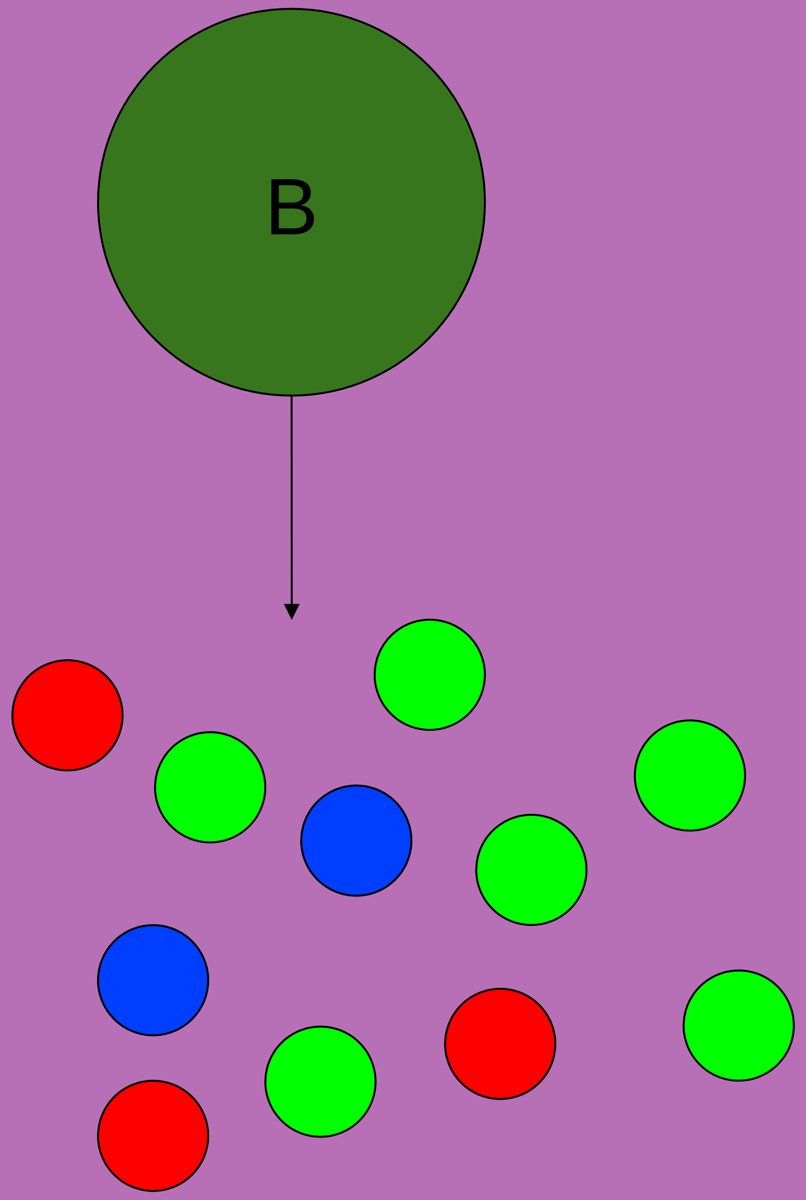
A can decay and produce certain groups of particles.

If its colour is conserved then we can use those produced by decay to figure out what came before.

A has an RGB of 2 red to 4 green with 1 blue. So it's children will also share that. Any combination that keeps that ratio can appear.



B:



Since B is a different shade of green it's children will be similar but not the same.

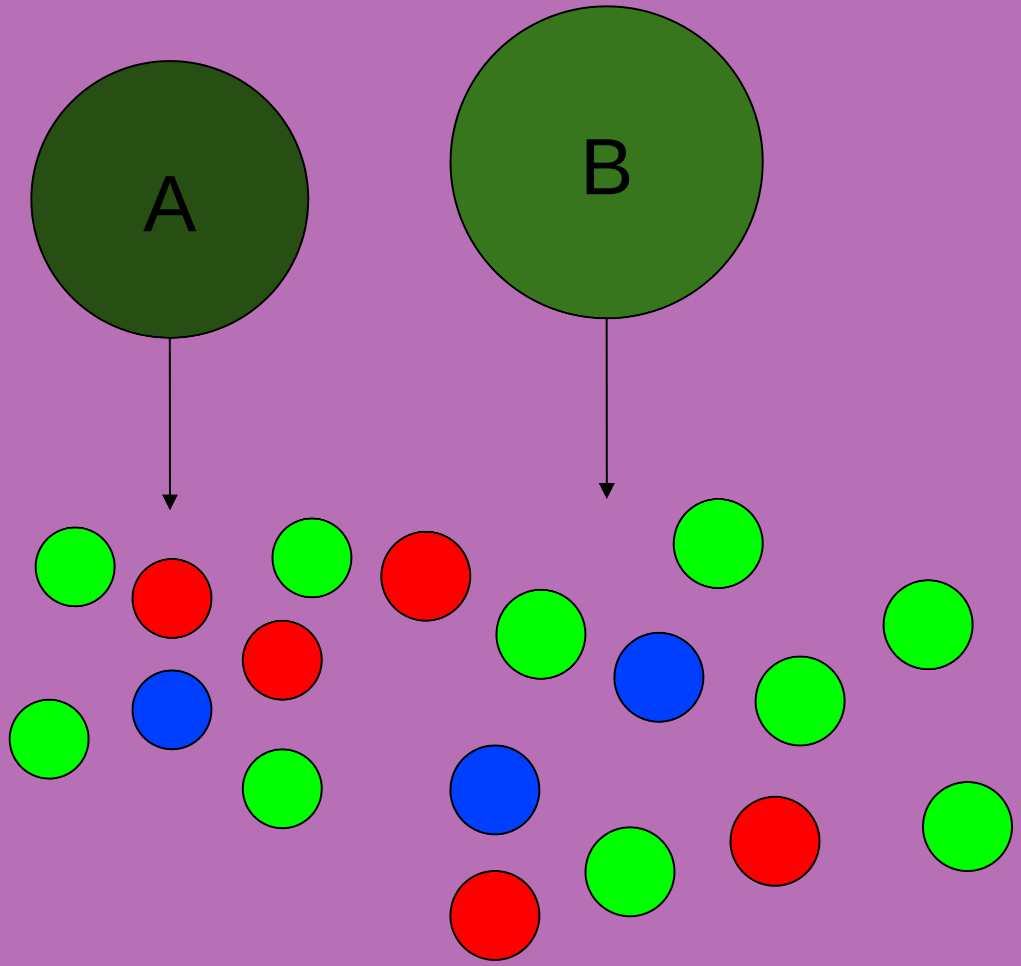
This colour is 3 parts red, 6 parts green and 2 parts blue.

In reality detecting these particles is really hard so you can miss them. Missing pieces is what makes particle physics really challenging.

In real detectors particles can be present but go undetected.

So large scale studies are carried out to gather enough data to statistically prove what is there. Otherwise you may get it confused for something else.

And for particles have similar kids, we can use how often the different groupings are made to tell them apart.



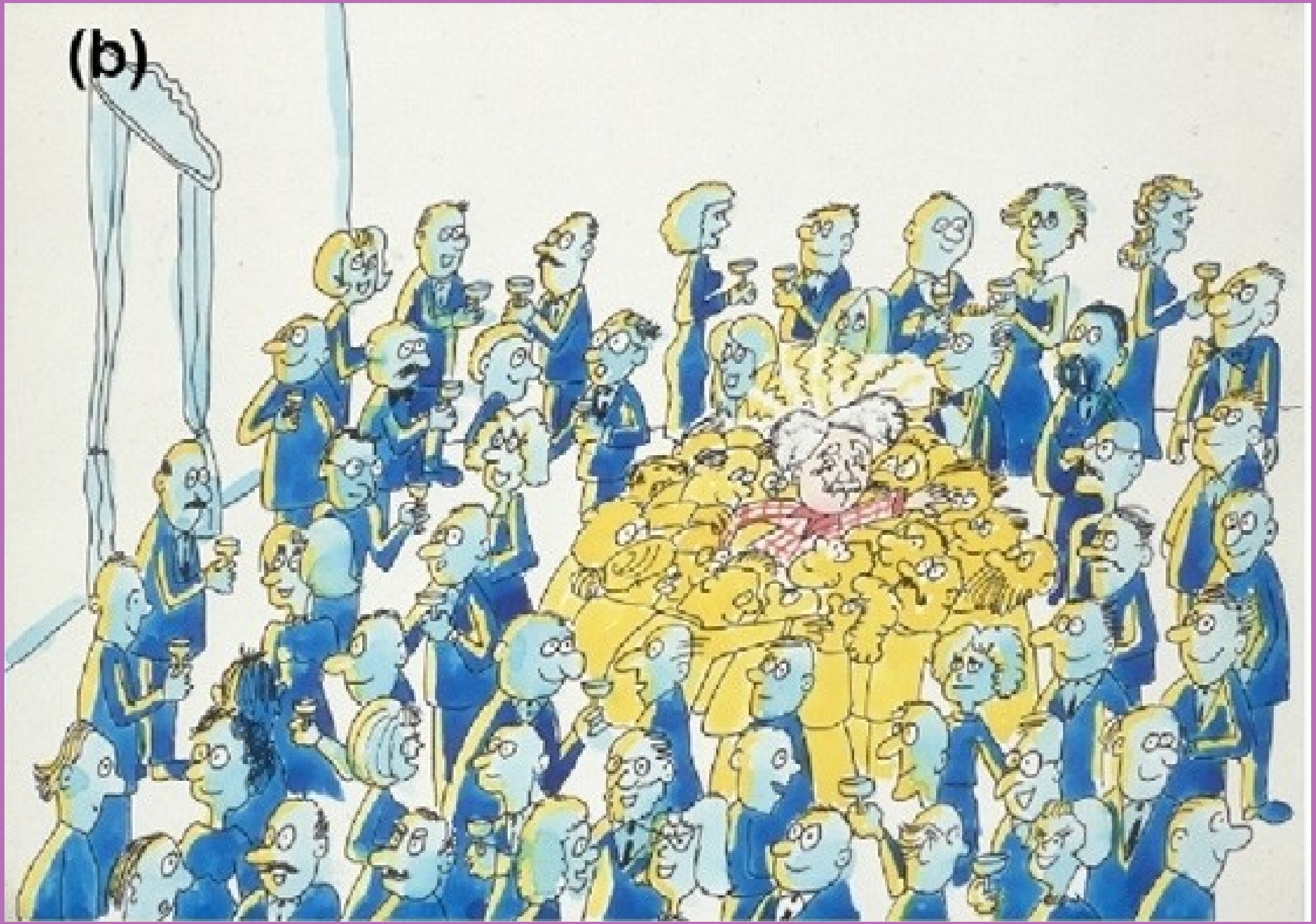
Higgs field:

The higgs field is the reason mass exists.

To describe it we use the idea of Einstein walking into a pub.

As he enters the pub, hes crowded by scientists desperate for collaborations.

They slow him down and make him seem much slower than he should be.



Not everybody has this problem though.

A shouty man come rushing in to spread the news that the prince has passed.

Unlike Einstein the news is quickly spread through the room.

Particles behave in the same way.

As they travel through the higgs field they gain higgs bosons, giving them mass.

Higgs Boson:

This particle seems to be responsible for mass.

So its casually known as the God particle to physicists.

It's responsible for mass.

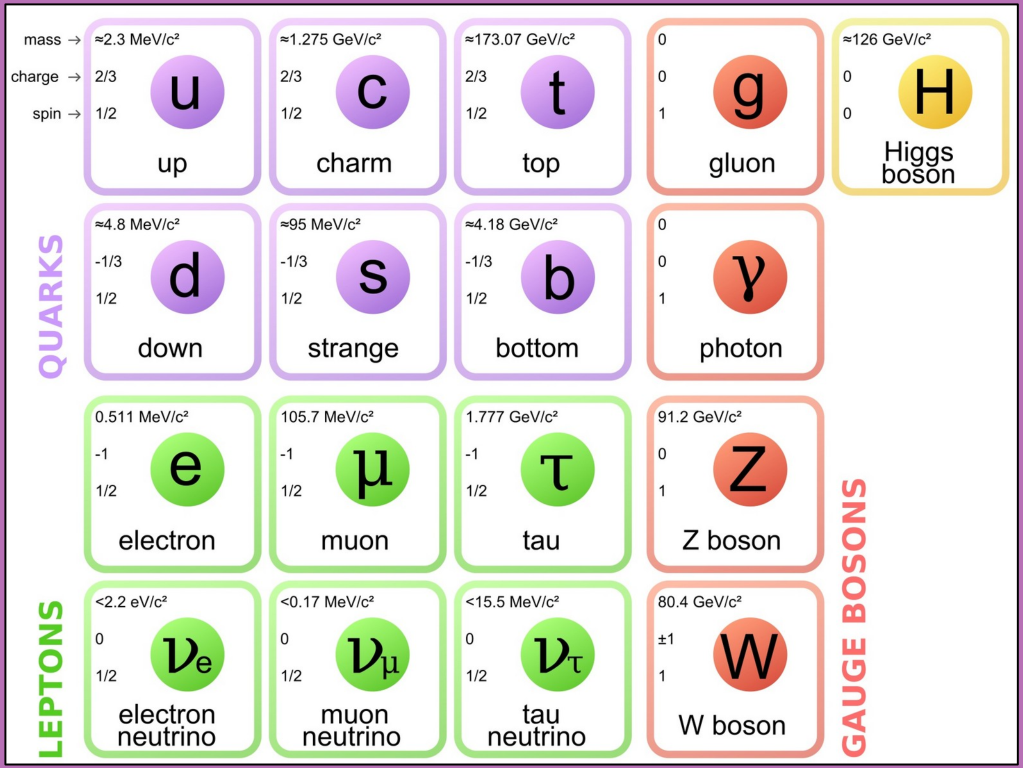
A mystery particle is found to have energy, E = 230 GeV and momentum, $P = 1.5 \times 10^{11}\, eVC^{-1}$

Find the mass of the particle, and then see if you can identify it using the standard model.

a) Higgs boson

b) Strange

c) Top



c) top

$$
\begin{aligned}
mc^2 &= \sqrt{E^2 - p^2c^2} \\
&= \sqrt{\left(230 \times 10^9 \text{ eV}\right)^2 - \left(1.5 \times 10^{11} \text{ eV}\right)^2} \\
&= 1.74 \times 10^{11} \text{ eV} \\
&= 174 \, \text{GeV}
\end{aligned}
$$

What's the Mass energy of the Top quark?

Histogram Analysis

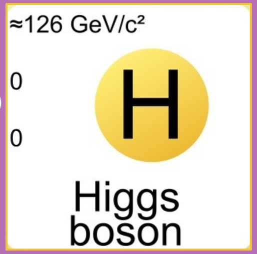
Want to play at being a mad scientist?

How about a Cern scientist?

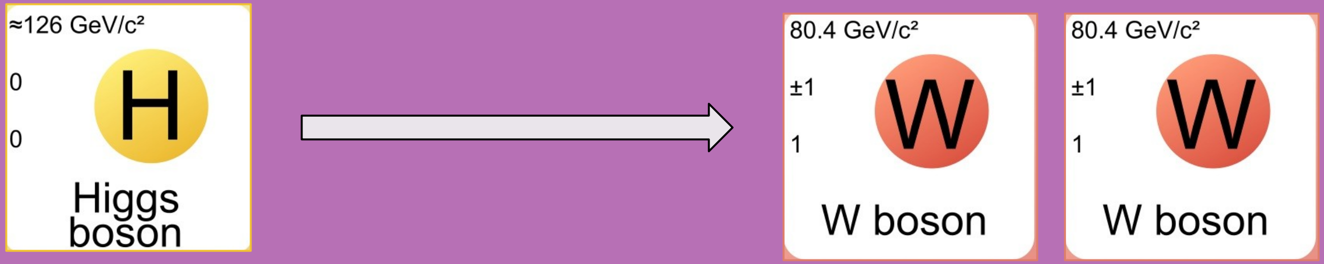
You do! Get ready, IT'S TIME FOR

STATISTICAL ANALYSIS!!!

How to find Higgs?

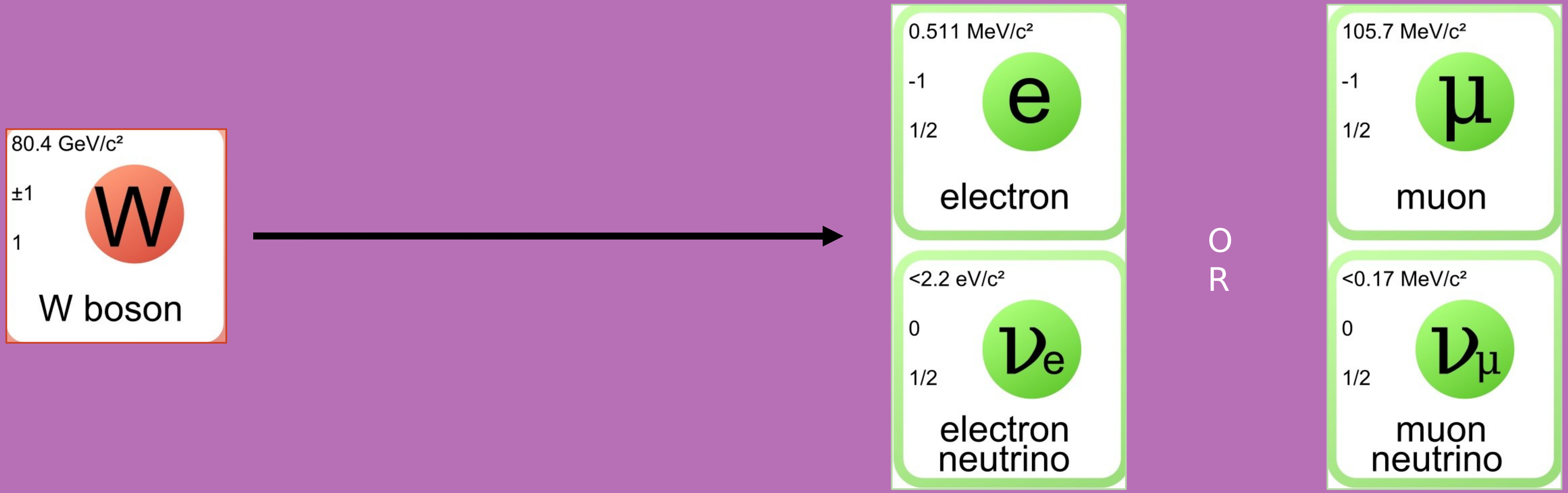


The higgs will most likely decay into the W+ and W-



These W bosons then decay into detectable particles.

The W- into an electron or muon, with the matching neutrino



W+ does the same but into the anti-matter version.

At

[Open Data and Tools for Education]()

You can find the ATLAS Histogram analyser.

Click on the simulated and real tab to see this set up.

Cern collects Terabytes of data so tools like the histogram analyser help