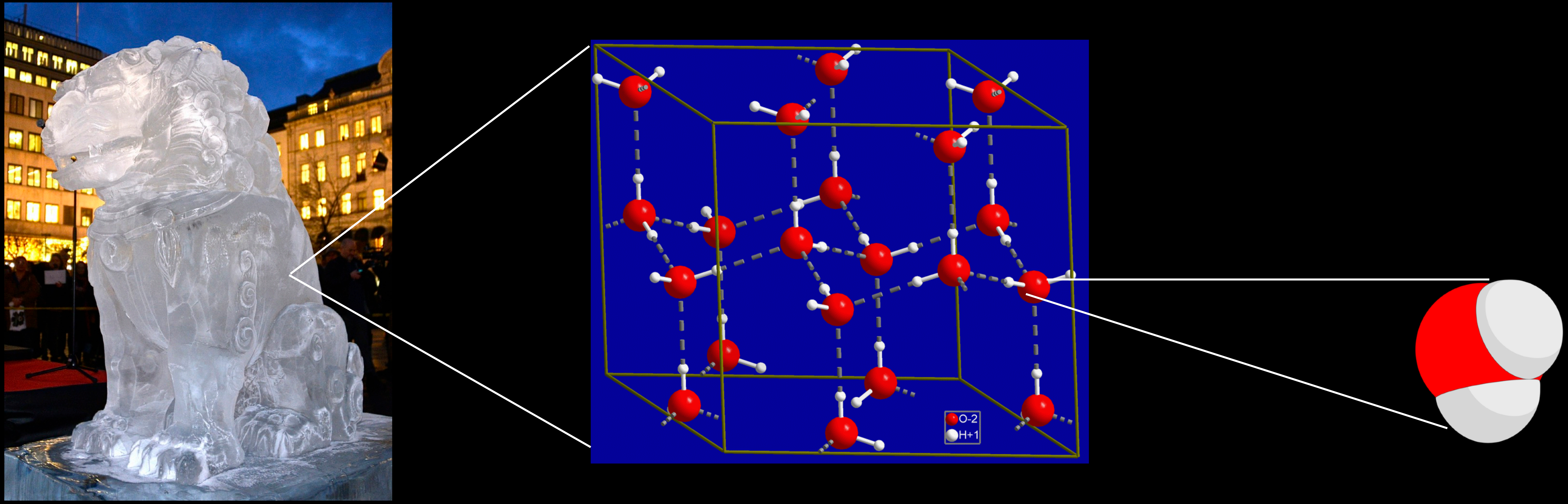
The lives of the particles

(and the physicists that study them!)

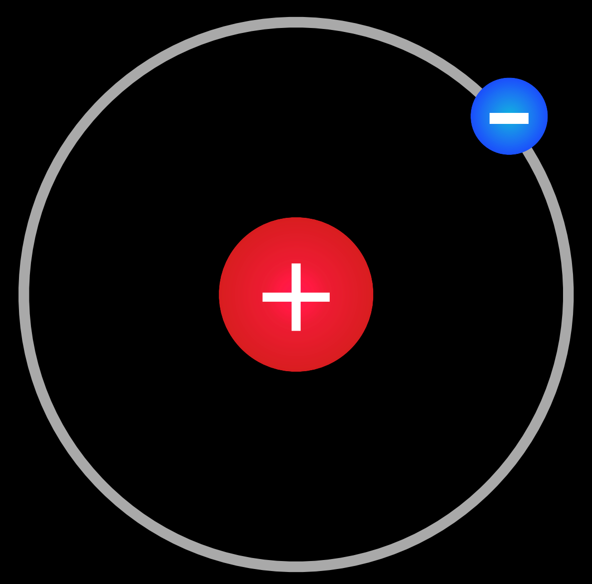
Sophie Renner, Stewarton Academy Talk, 30th March 2023

Zooming in…

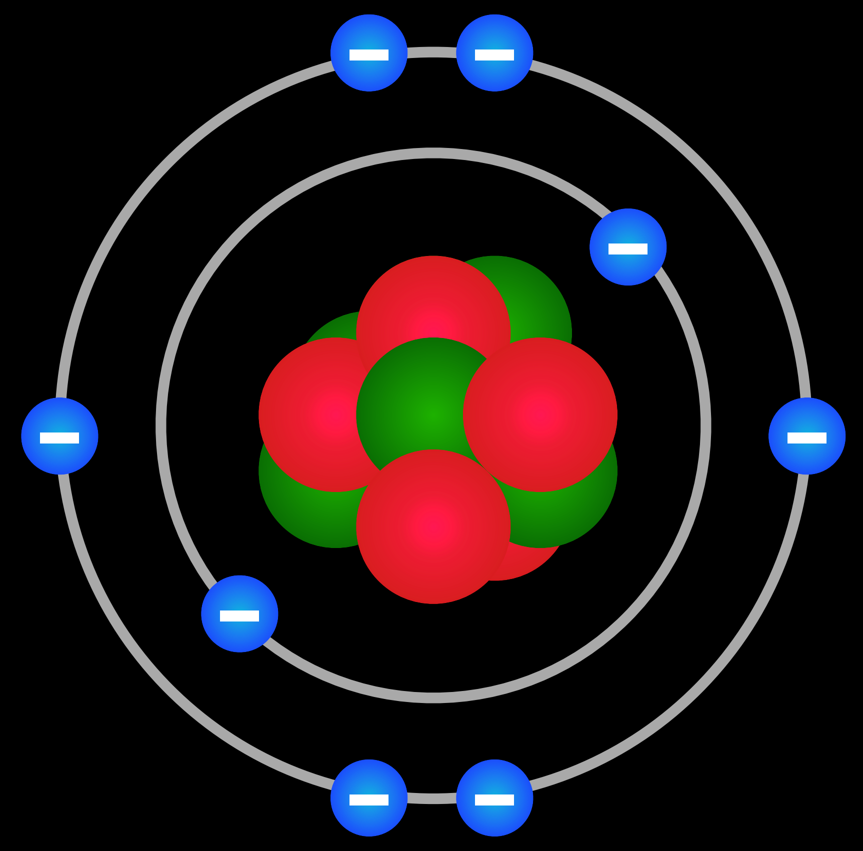


The protons, neutrons and electrons

Every atom is a combination of just three particles



hydrogen atom



oxygen atom

Where did these particles come from?

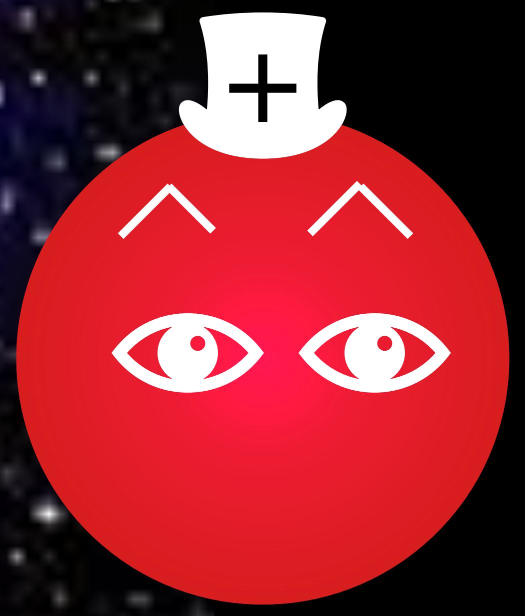
Big Bang

13.8 billion years ago….

…everything began

The birth of a proton

The universe started as an unimaginably hot, dense, ball of energy



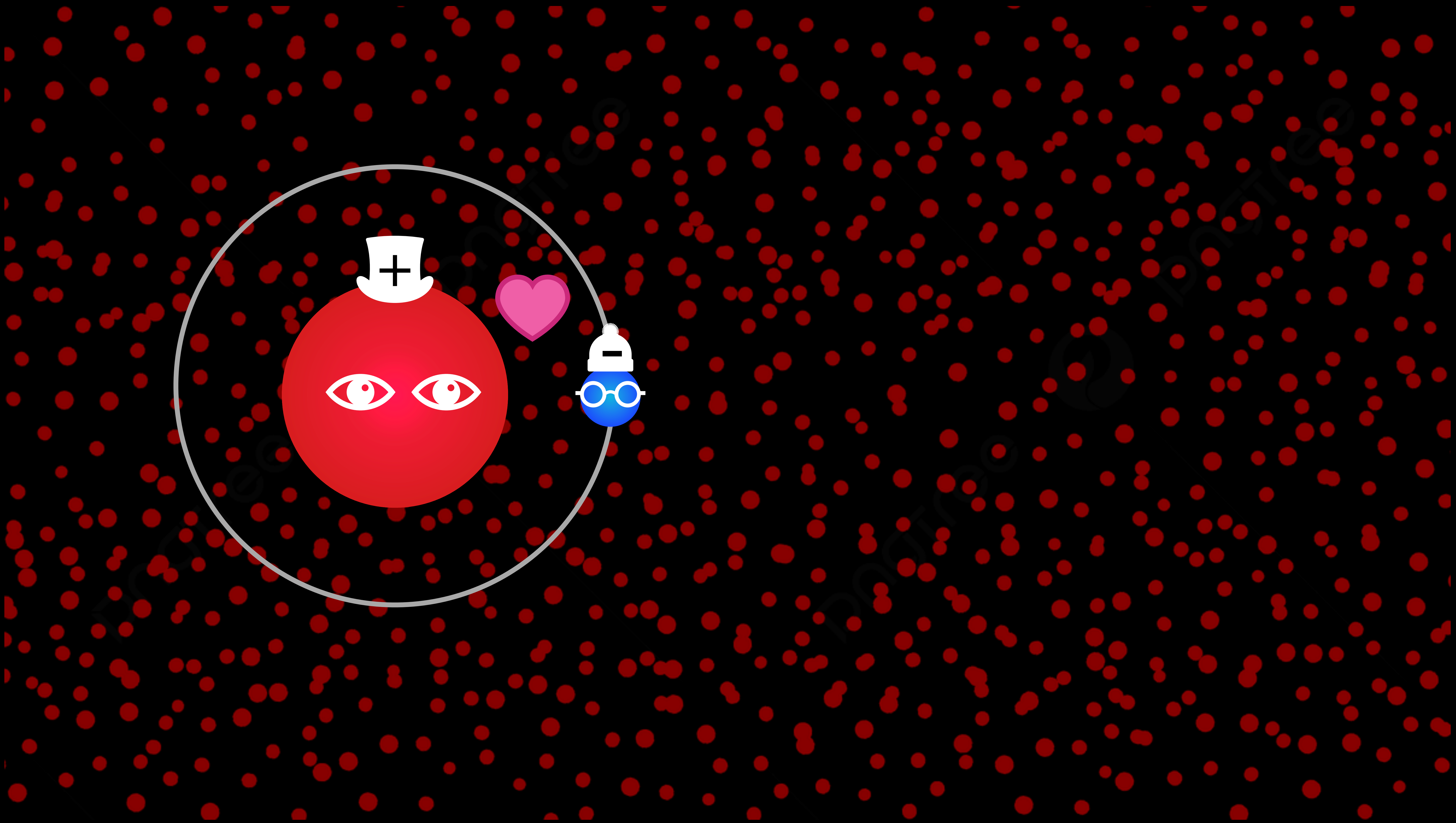
proton

electron

In less than a second, all the protons and electrons were formed

Forming atoms

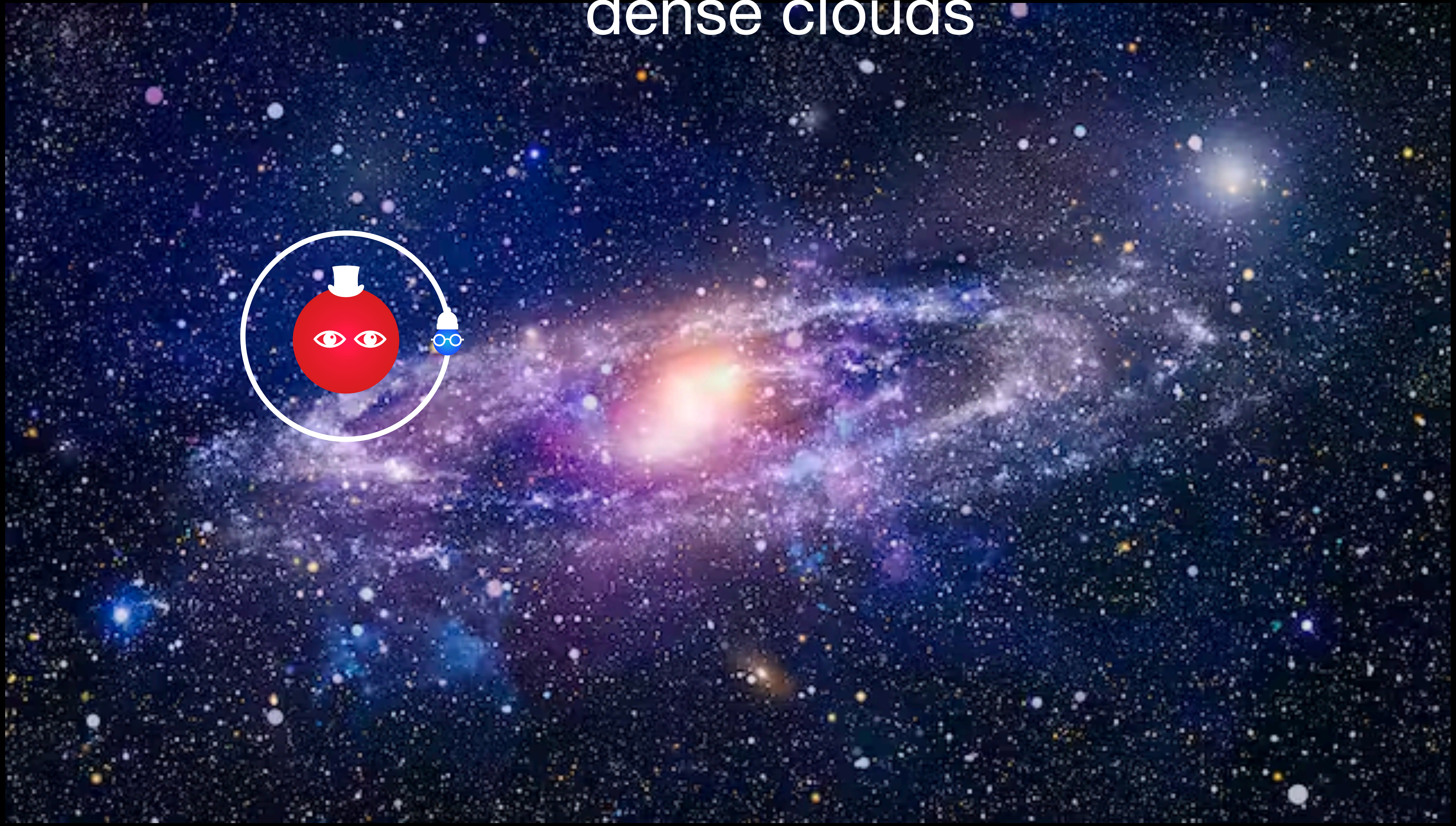
It took 379,000 years for the universe to cool down enough for atoms to form



Nearly all of these atoms were hydrogen (just one proton and one electron)

Stars and galaxies

As the universe expanded and cooled, gravity pulled the hydrogen gas into huge dense clouds



As these clouds shrank further, they formed the first stars, about 100 million years after the Big Bang

The rise of the neutrons

After the big bang, the only elements around were hydrogen, and a bit of helium

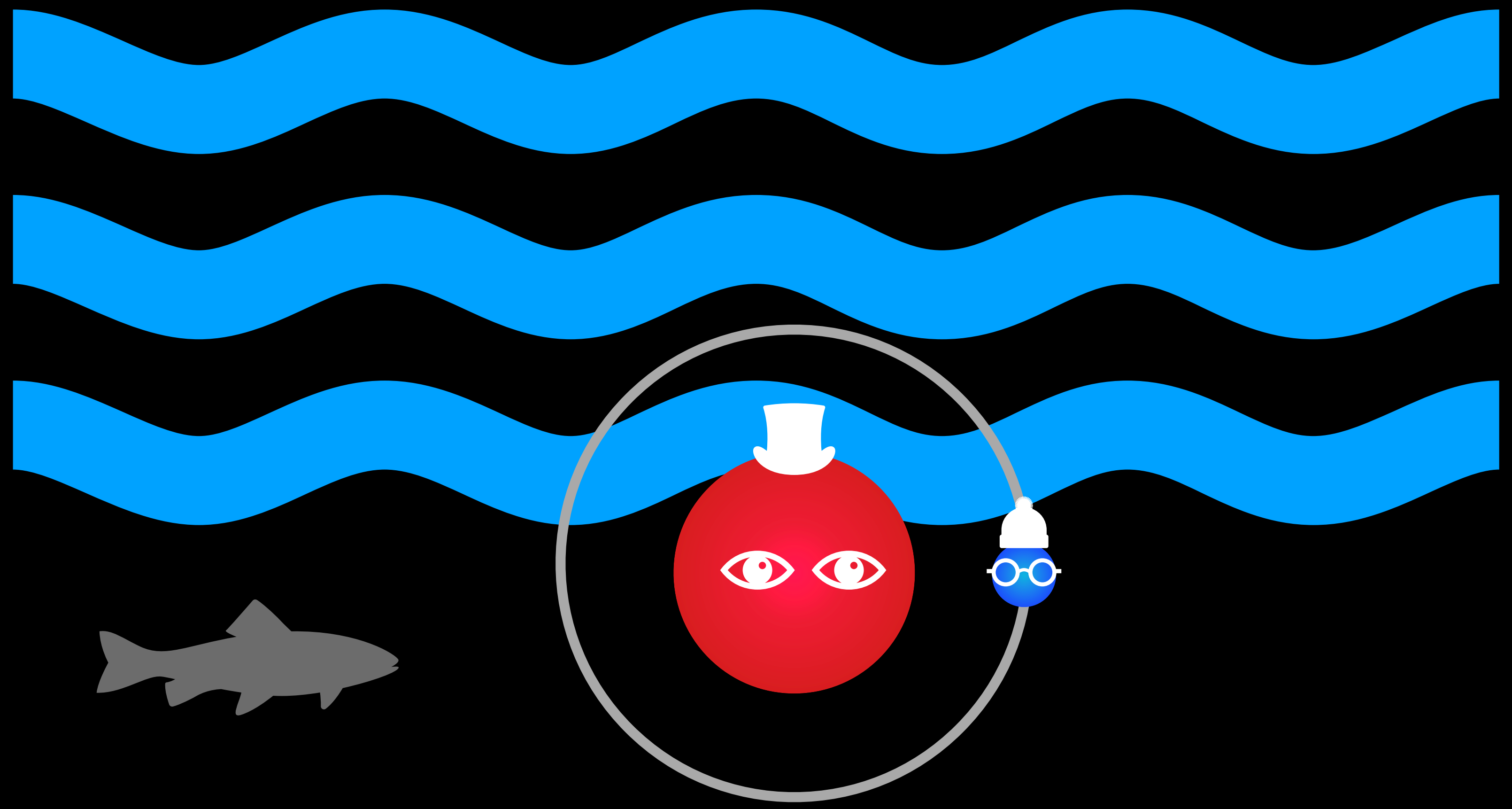
Other elements, with more protons and neutrons, were formed during the life and death of stars

Large stars generate elements by nuclear fusion

When they die, a supernova explosion flings these atoms through space

Dust and ashes

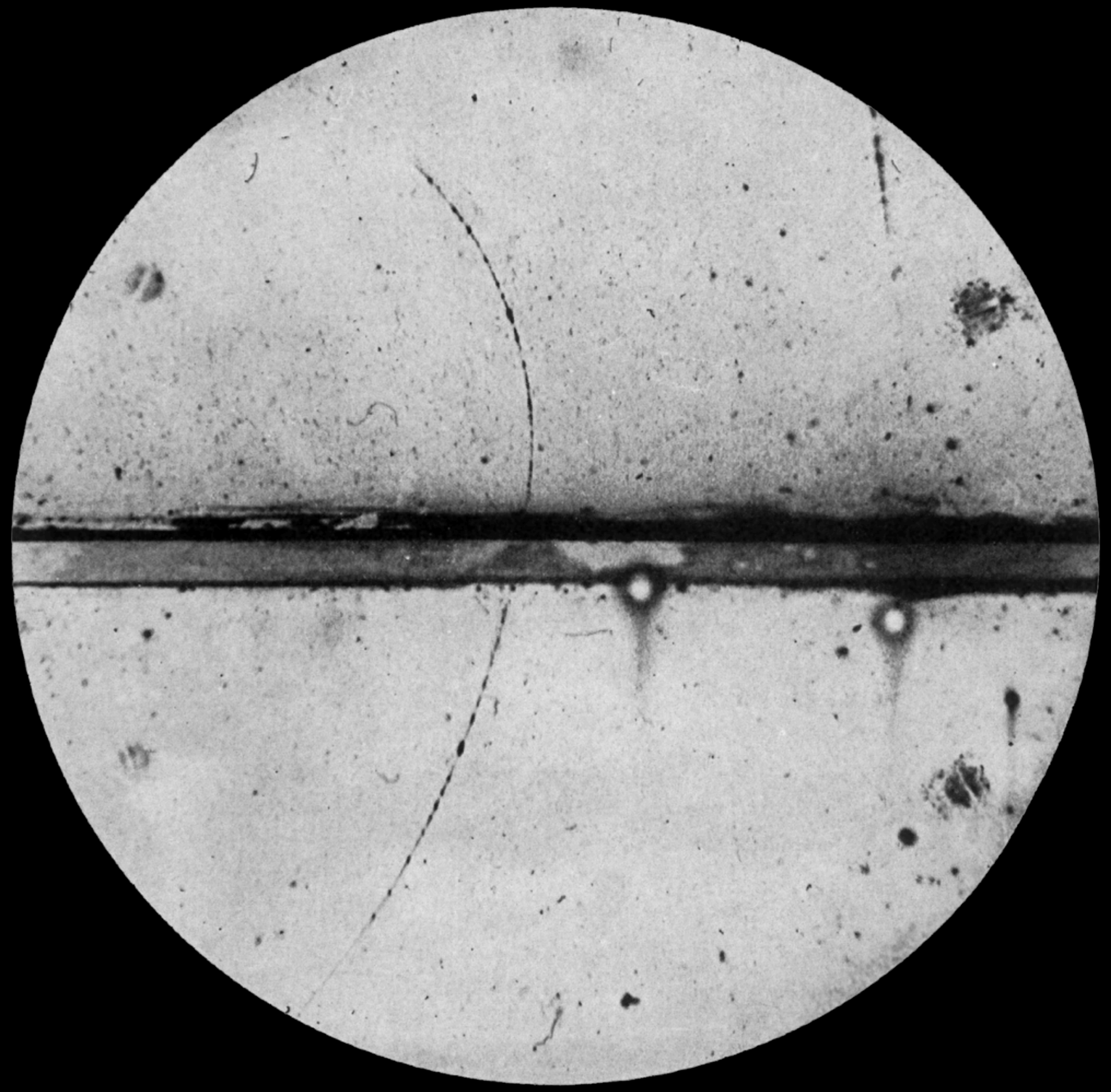
Some of the hydrogen atoms formed at the Big Bang, along with heavier atoms formed by stars, made up a cloud of gas which formed our Solar System about 5 billion years ago



On Earth, the hydrogen joined up with oxygen and became water

Is that all?

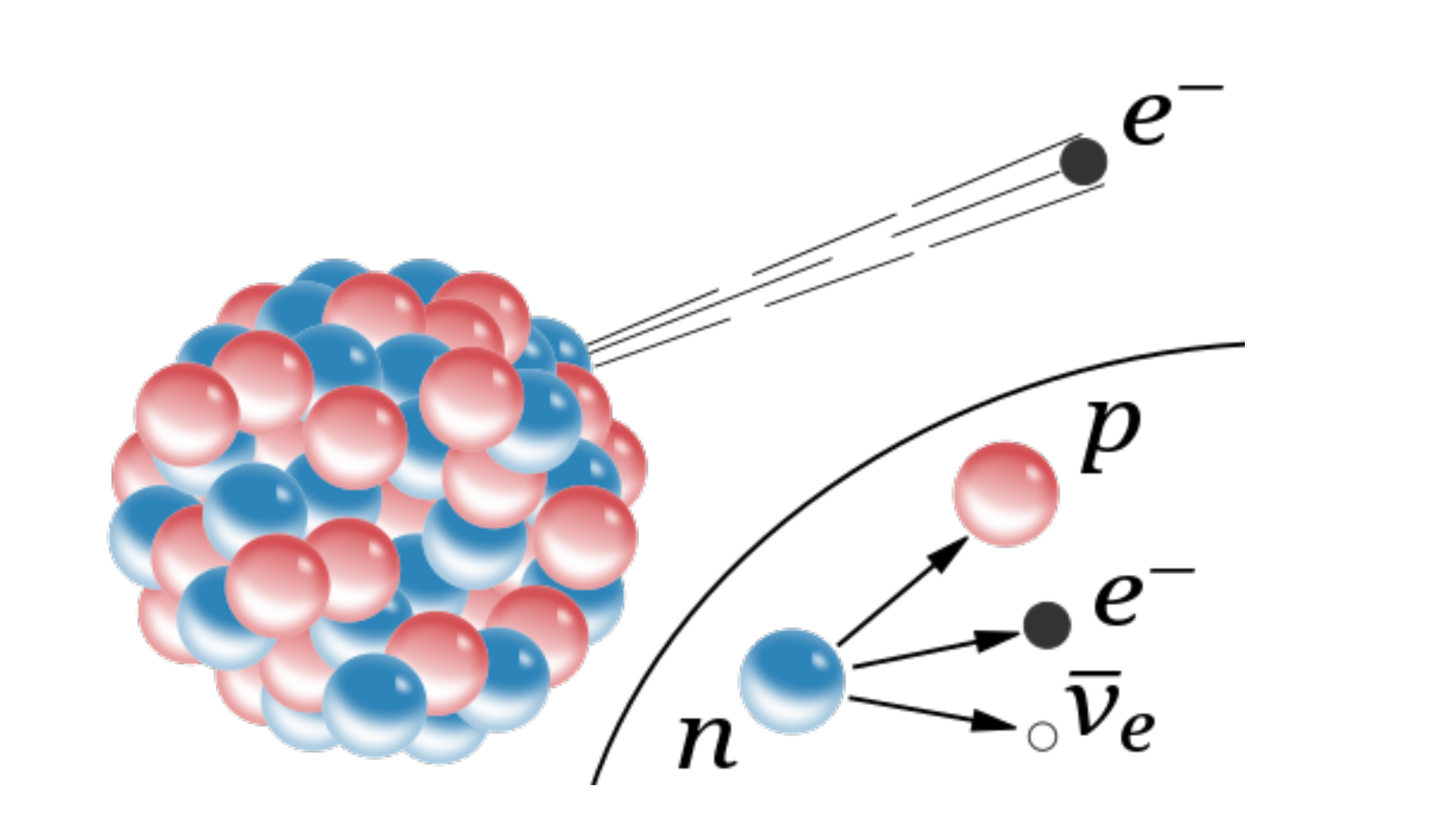
Protons, neutrons and electrons seem to be all that are needed to make our world



…But almost as soon as these particles were discovered, physicists started to see glimpses of others

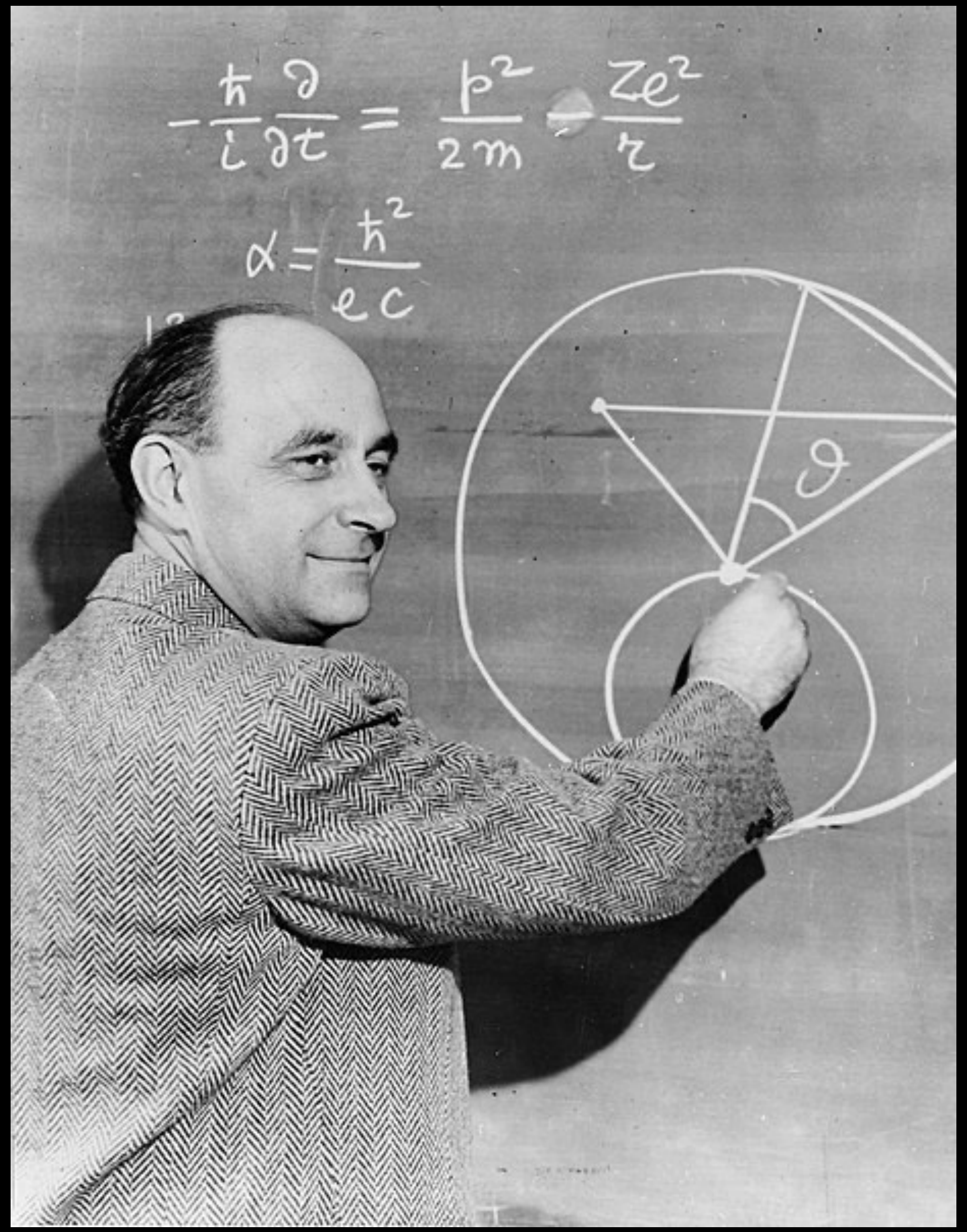
Invisible particles?!

In the 1930s, physicists realised that an invisible particle must be being produced in radioactive decays of heavy nuclei

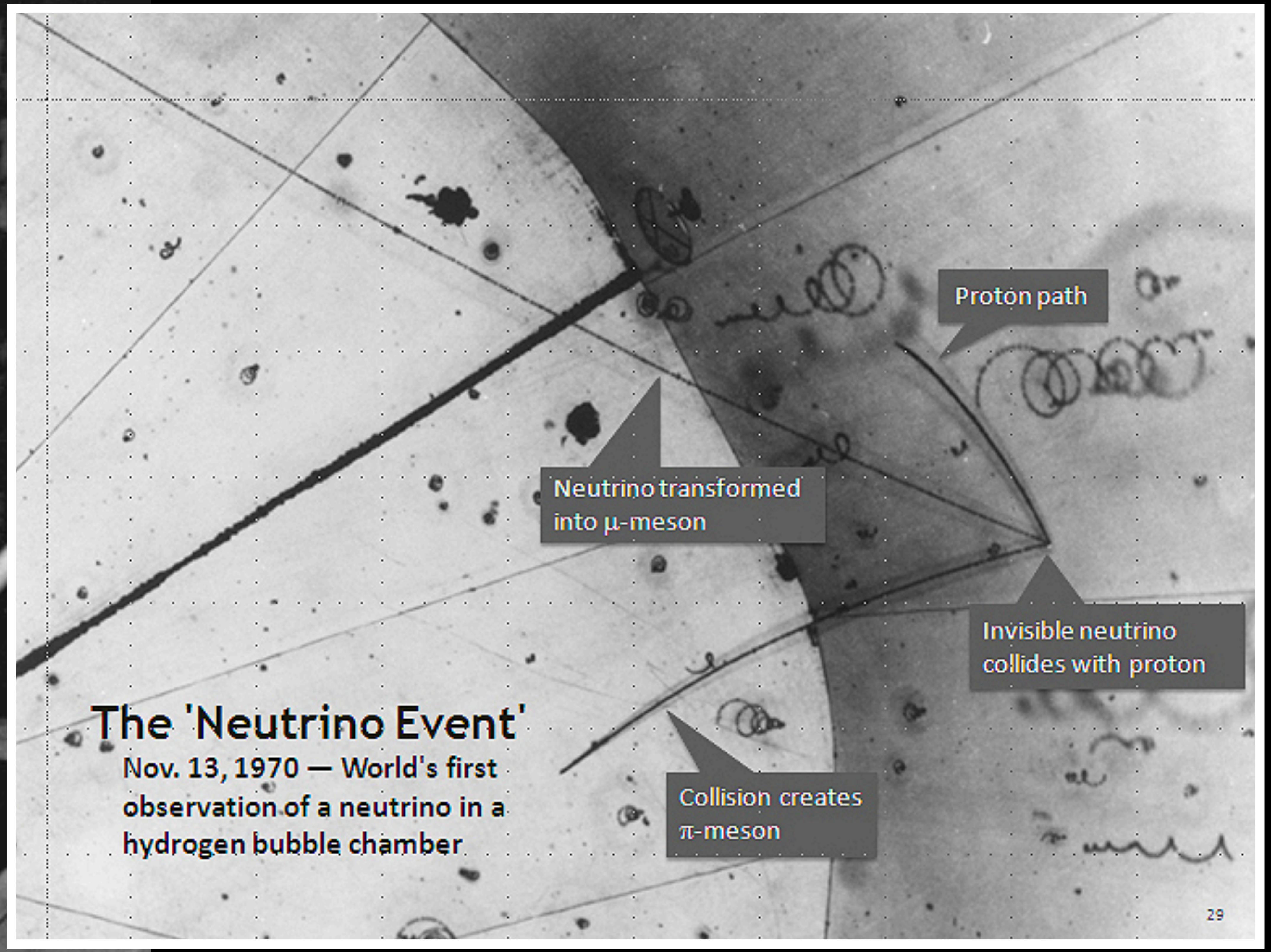


Enrico Fermi called this the **neutrino**

“little neutral one”



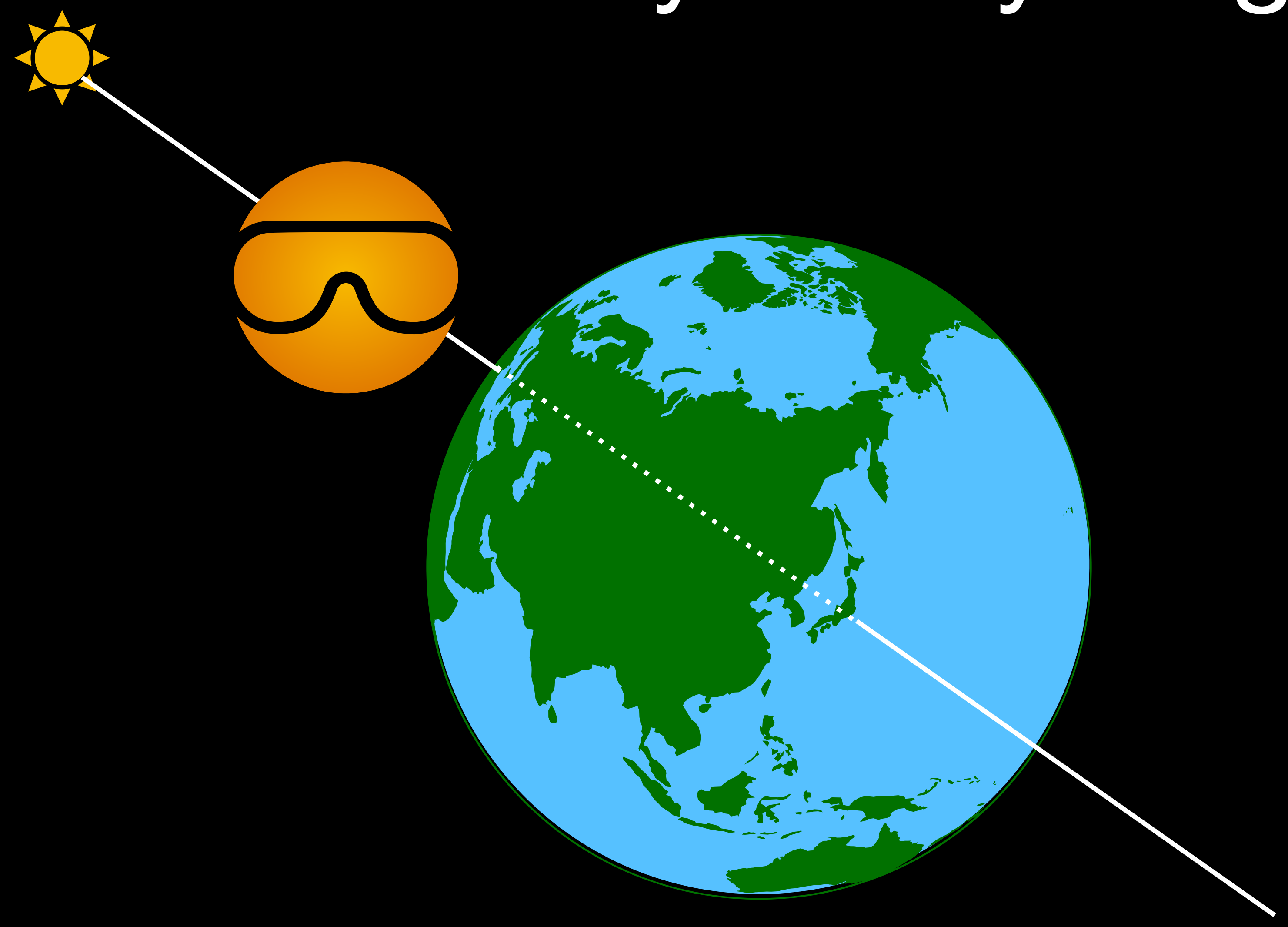
Invisible particles?!



The lonely life of a neutrino

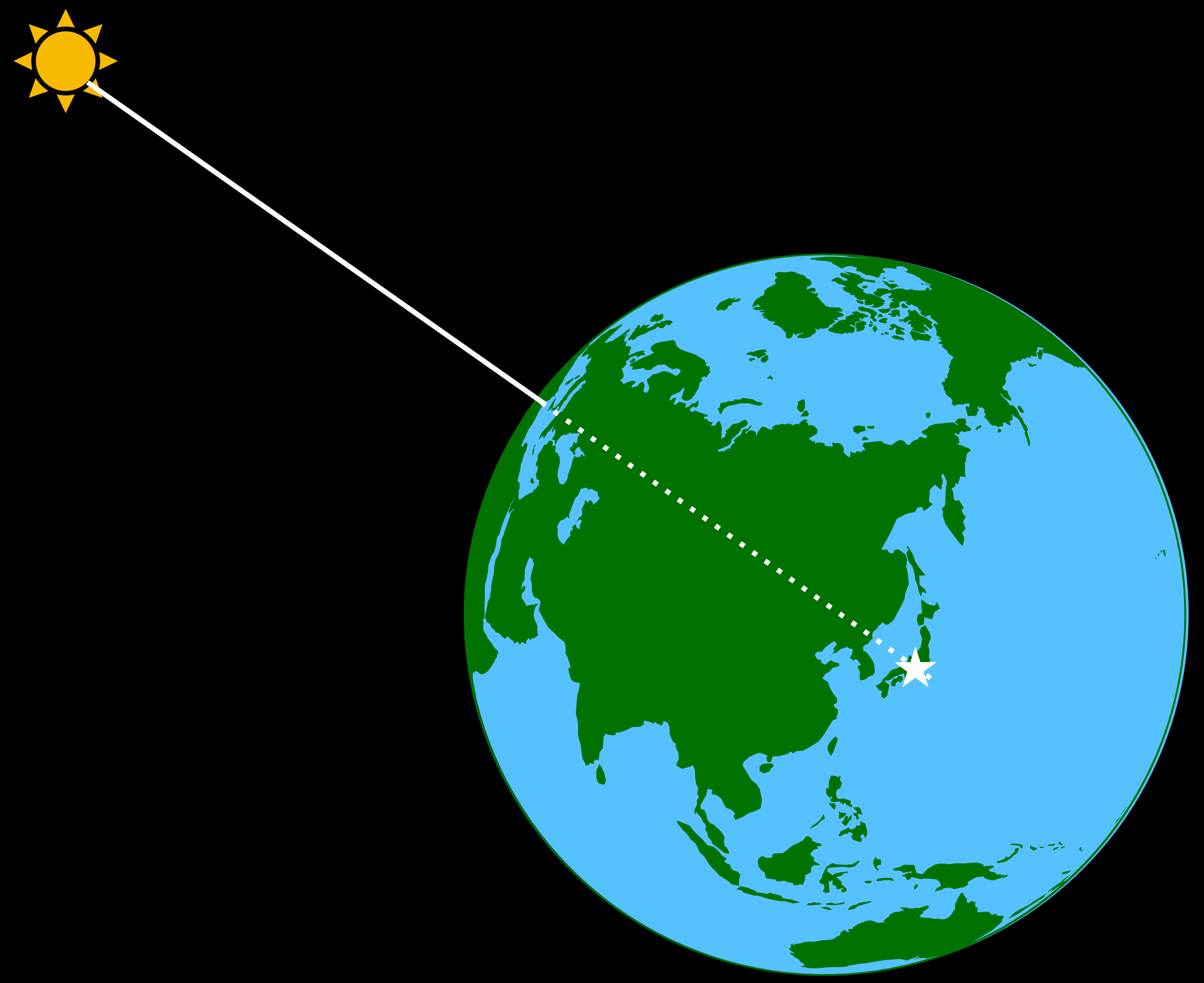
Trillions and trillions of neutrinos are born in the Sun every second

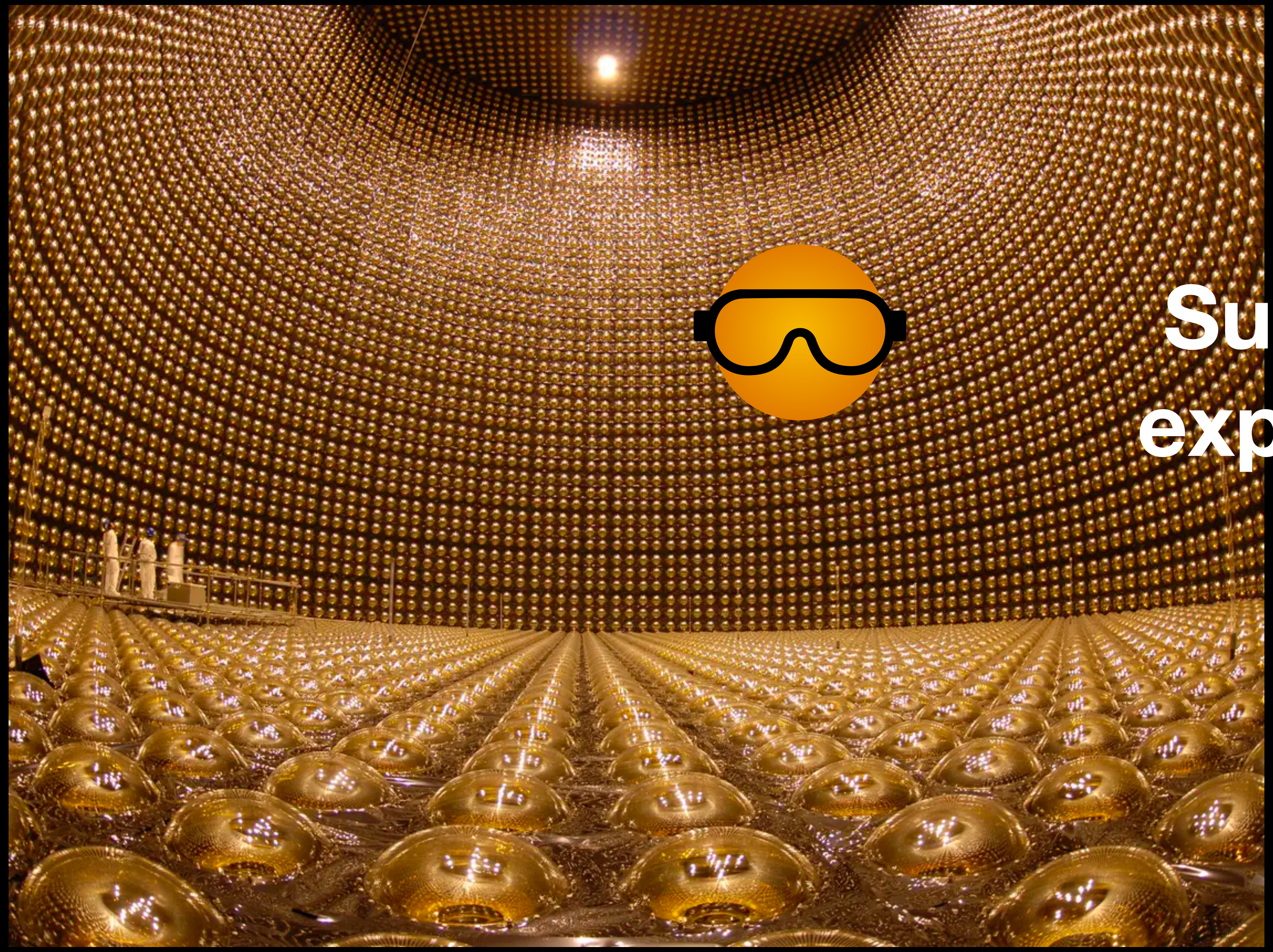
They nearly all go straight through anything in their way



The lonely life of a neutrino

Experiments hoping to catch them need to be enormous



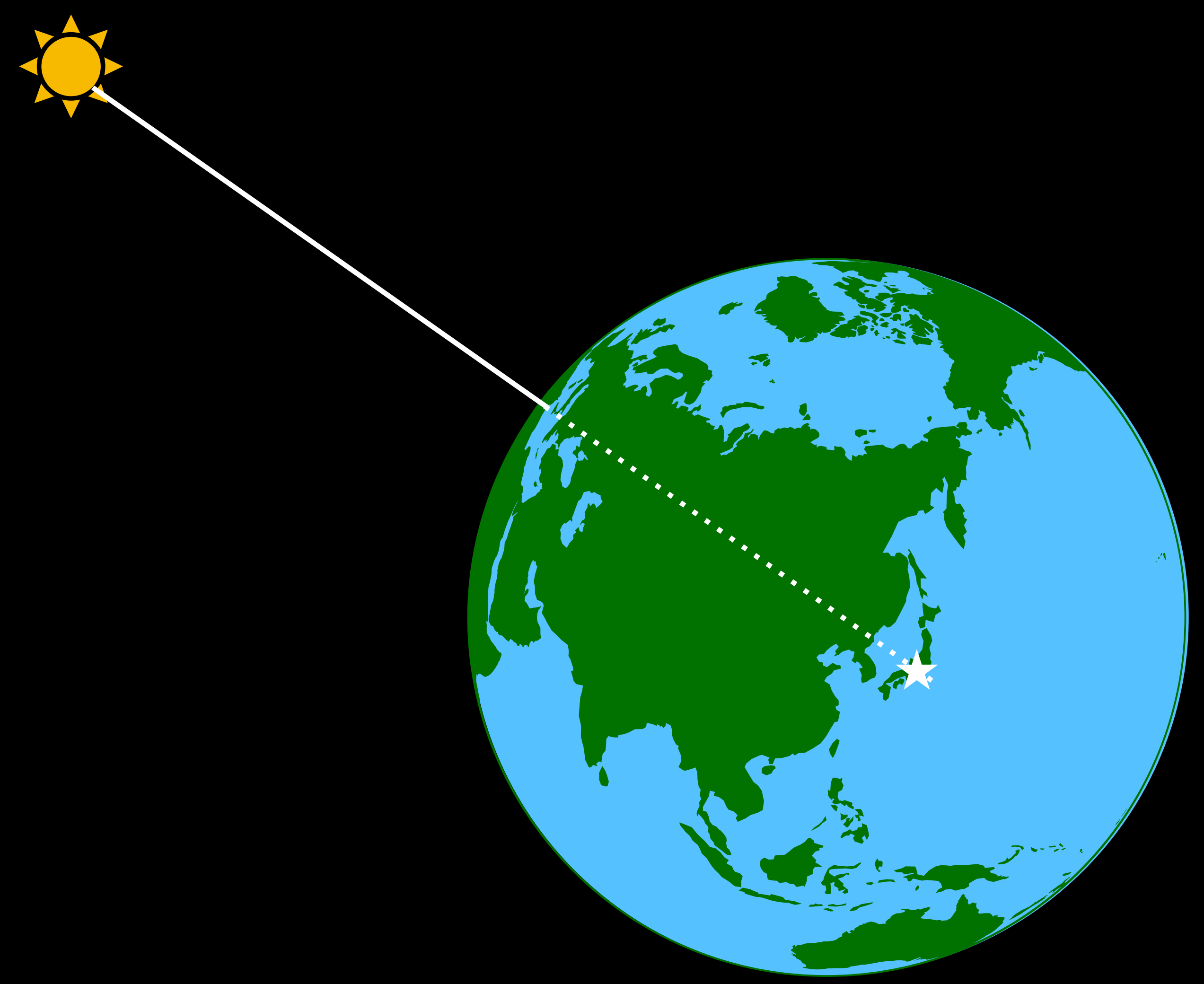


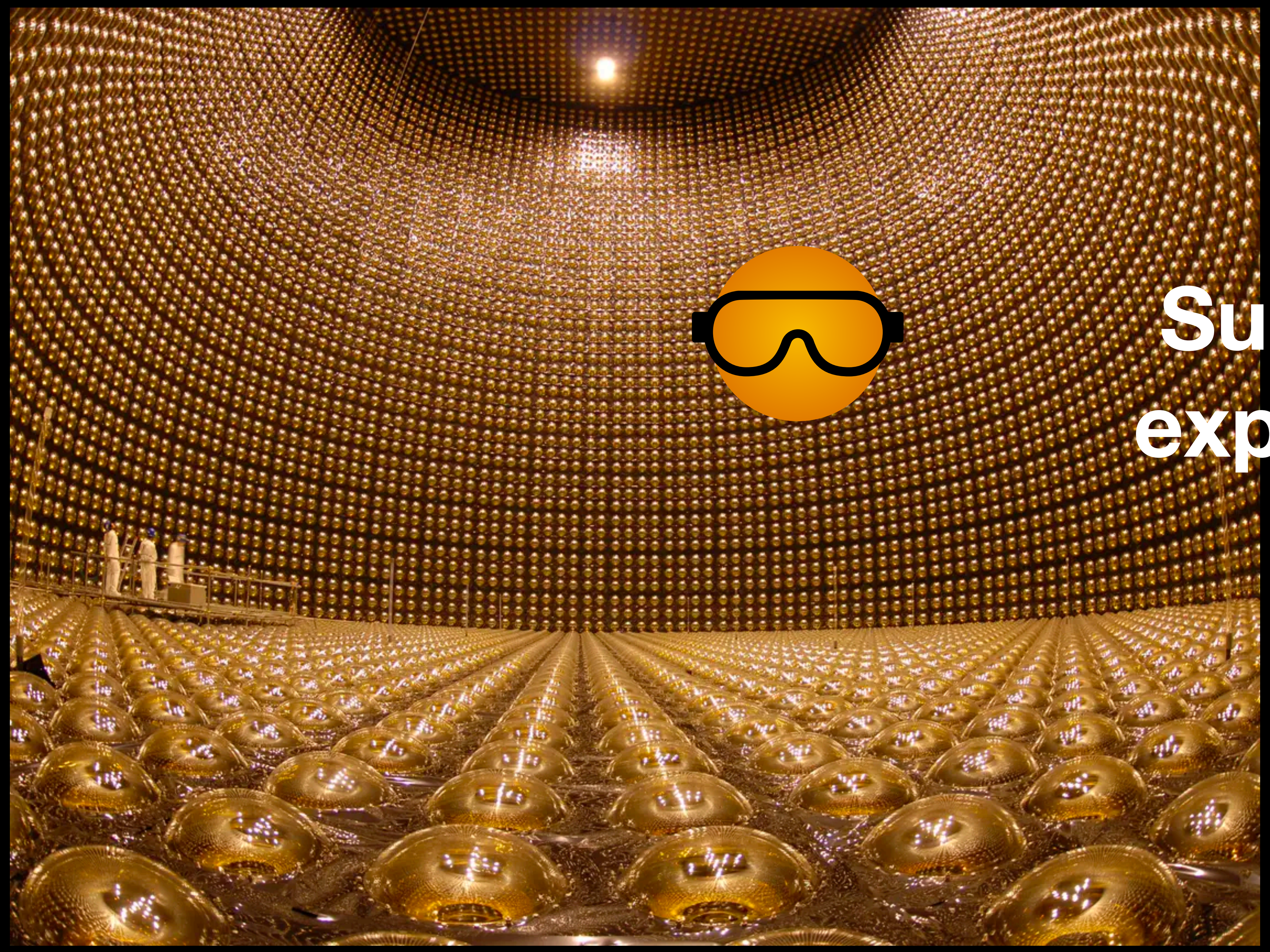
Super Kamiokande experiment in Japan

50,000 tons of water, surrounded by 11,000 very sensitive light detectors

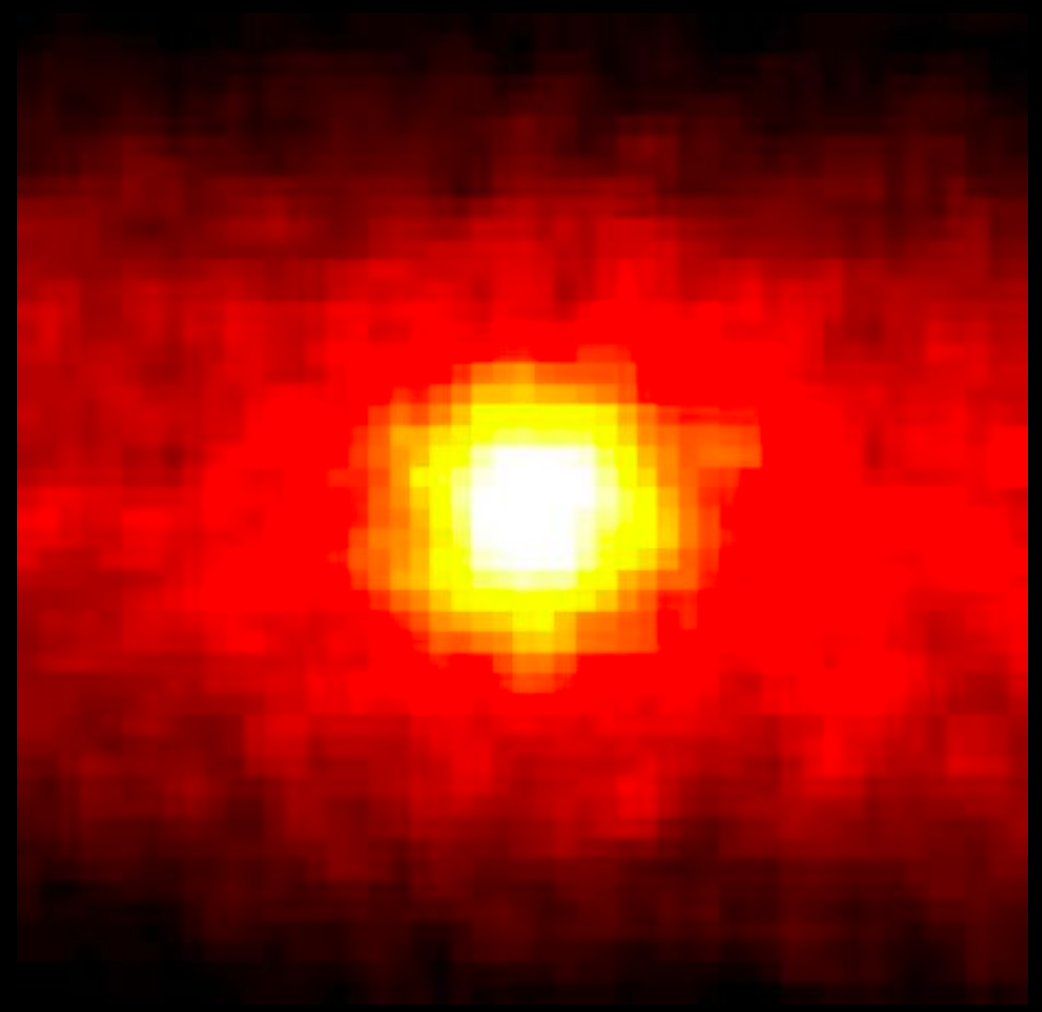
The lonely life of a neutrino

Experiments hoping to catch them need to be enormous





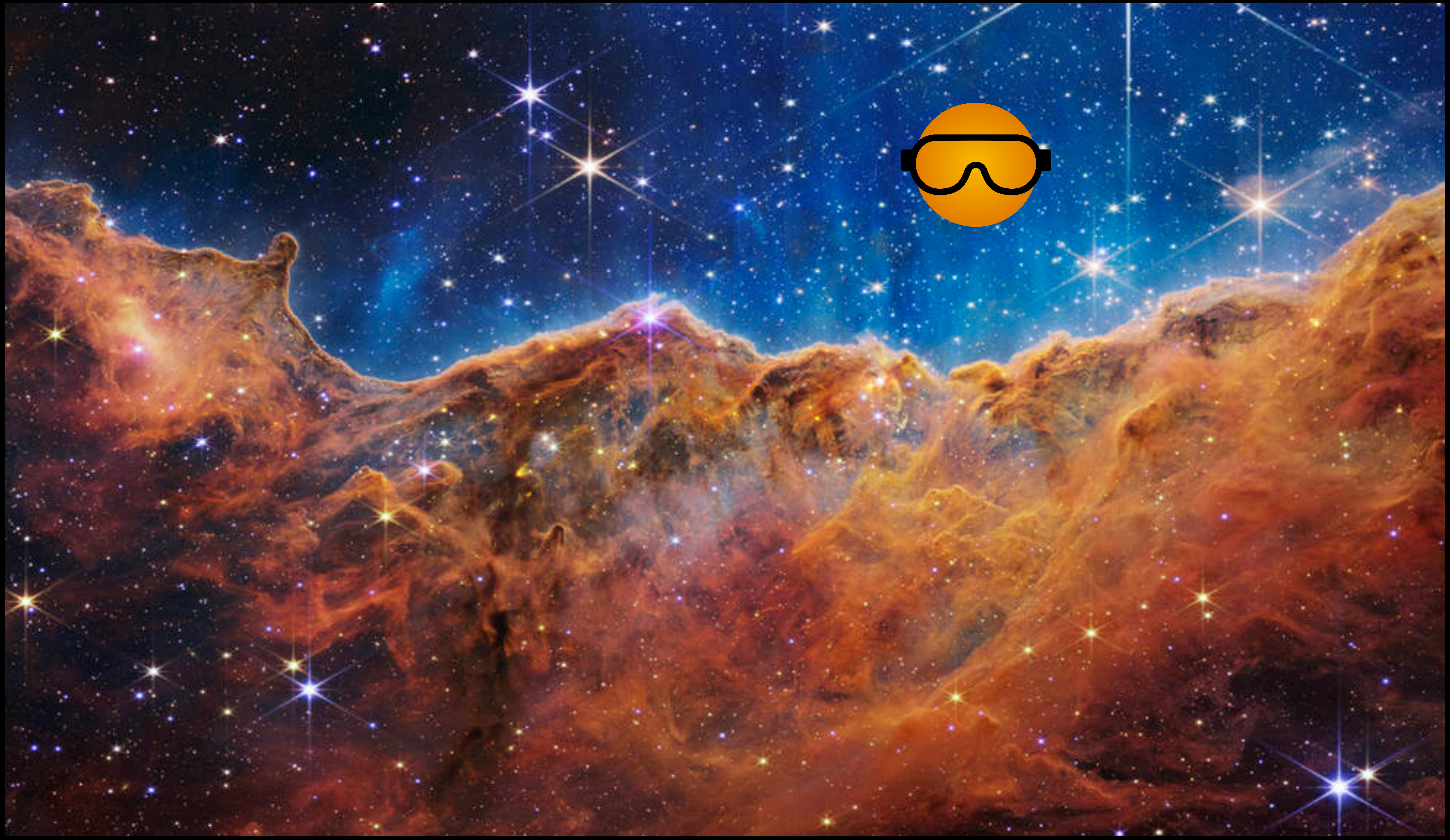
Super Kamiokande experiment in Japan



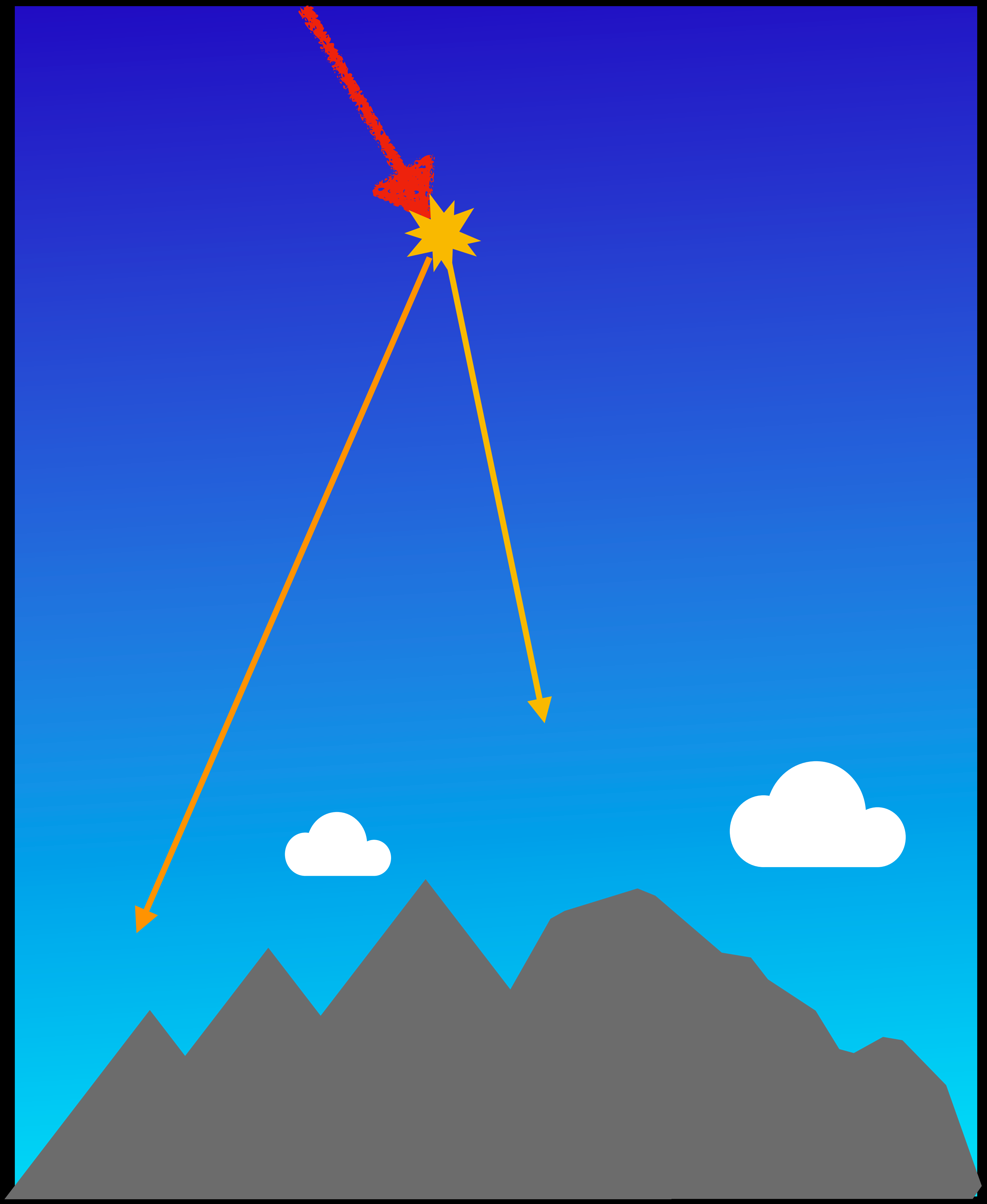
Picture of the Sun taken through the Earth

The lonely life of a neutrino

The vast majority of neutrinos will not be absorbed by anything, and will travel through space at close to the speed of light, forever



Muons - the electron's short-lived cousin



In the 1930s, American physicists were studying cosmic rays

They found a particle similar to an electron, but 200 times heavier

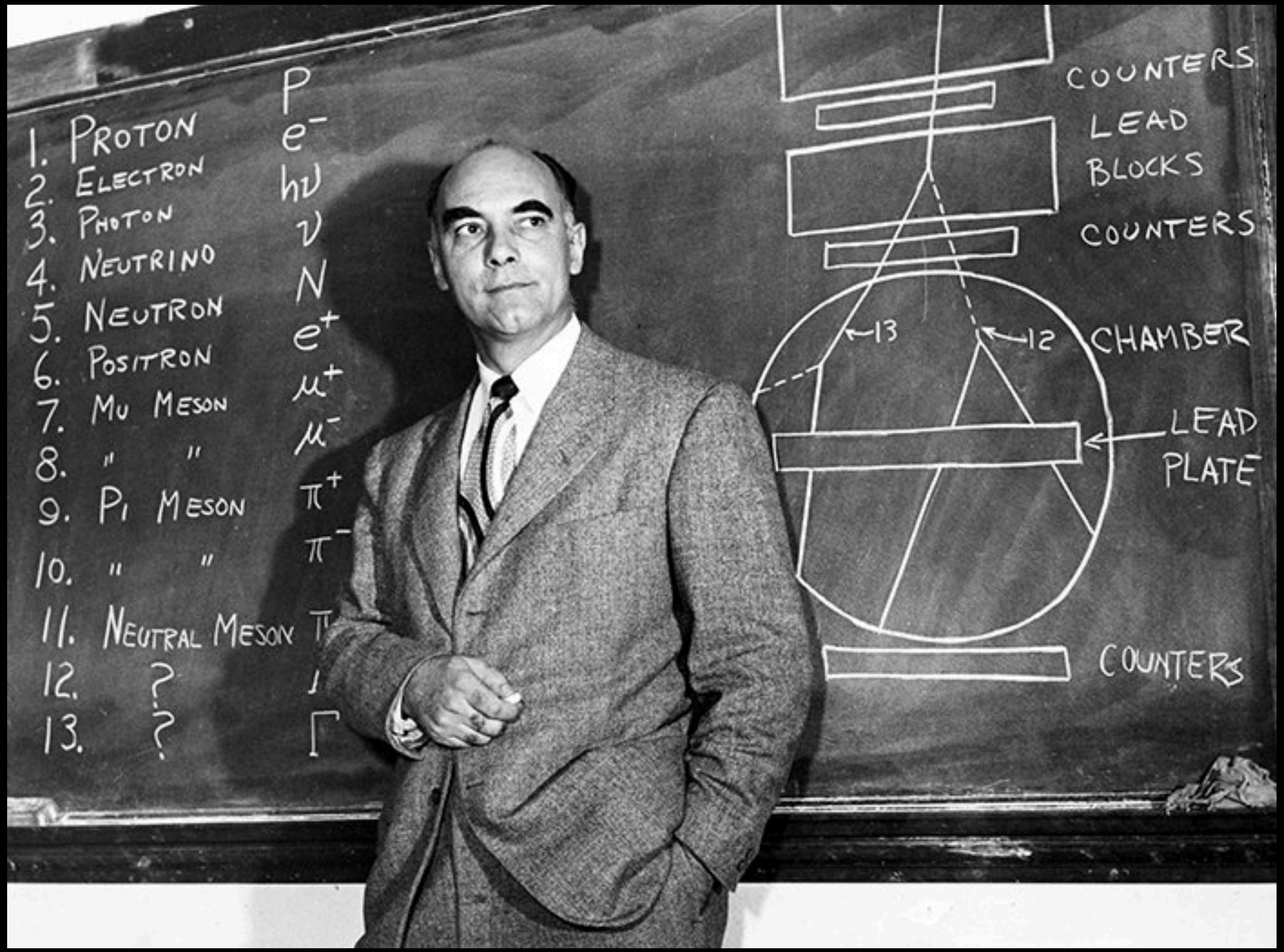
They only live for 2.2 microseconds

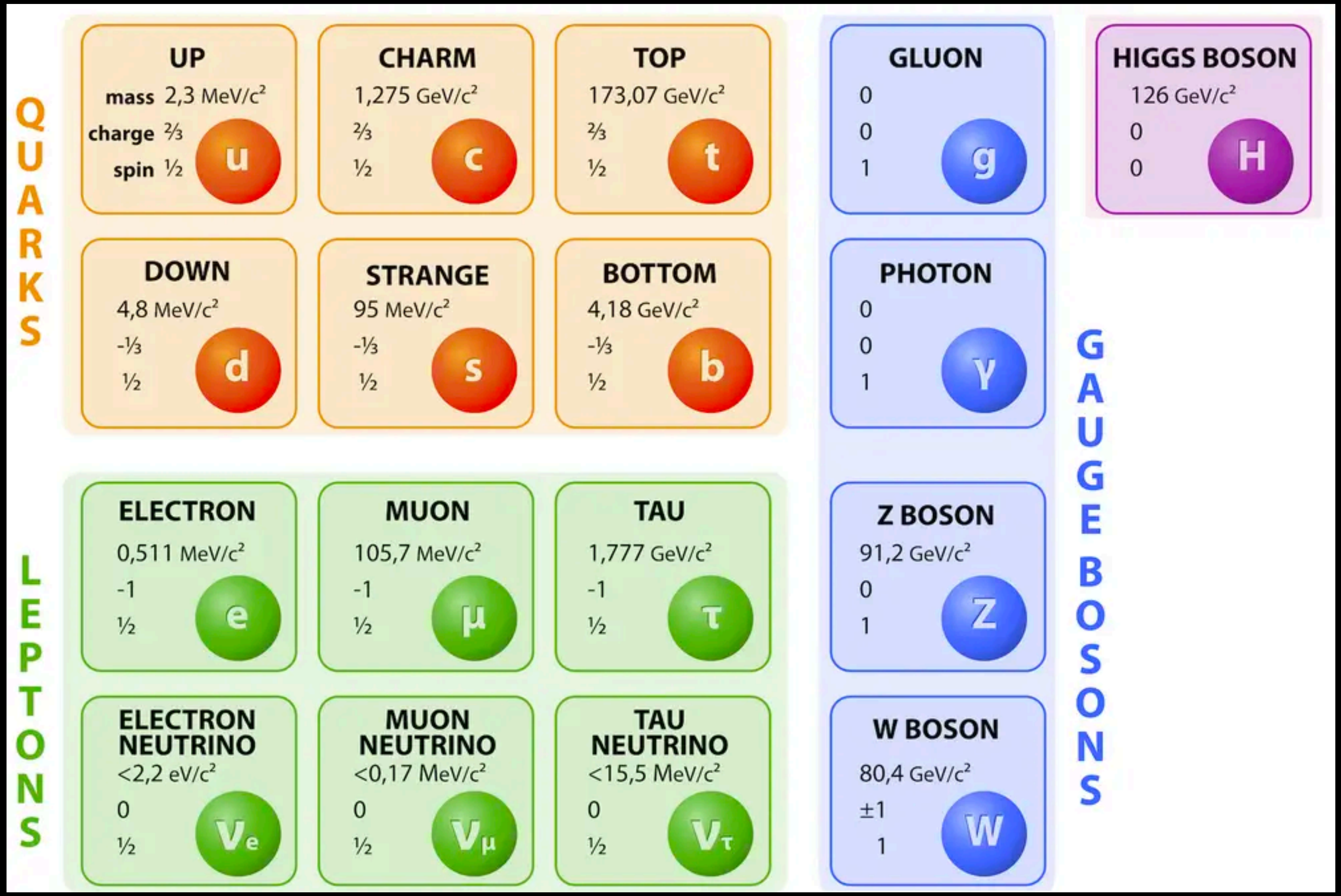
"Who ordered that?"
- Isidor Isaac Rabi

Muons - the electron’s short-lived cousin

The Standard Model

As physicists began to build up a picture of the particles they were finding, they started to piece together a theory of how it all worked



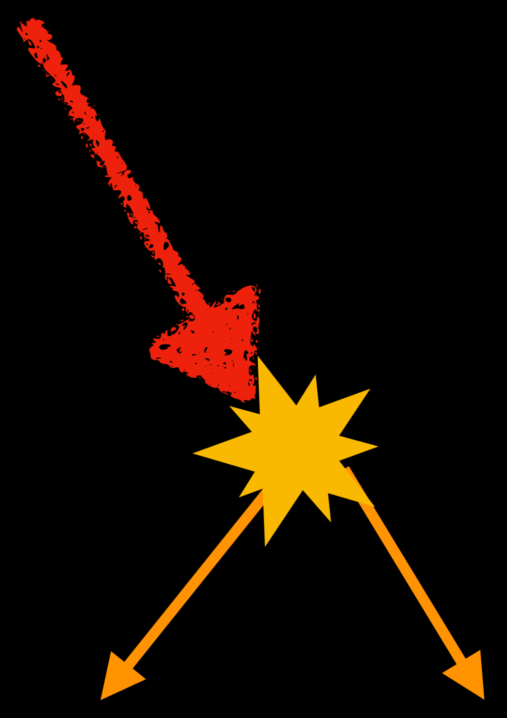


In doing so, they predicted new particles waiting to be discovered

Particle colliders

Short-lived particles were first discovered in cosmic ray showers

Very fast-moving particle from space



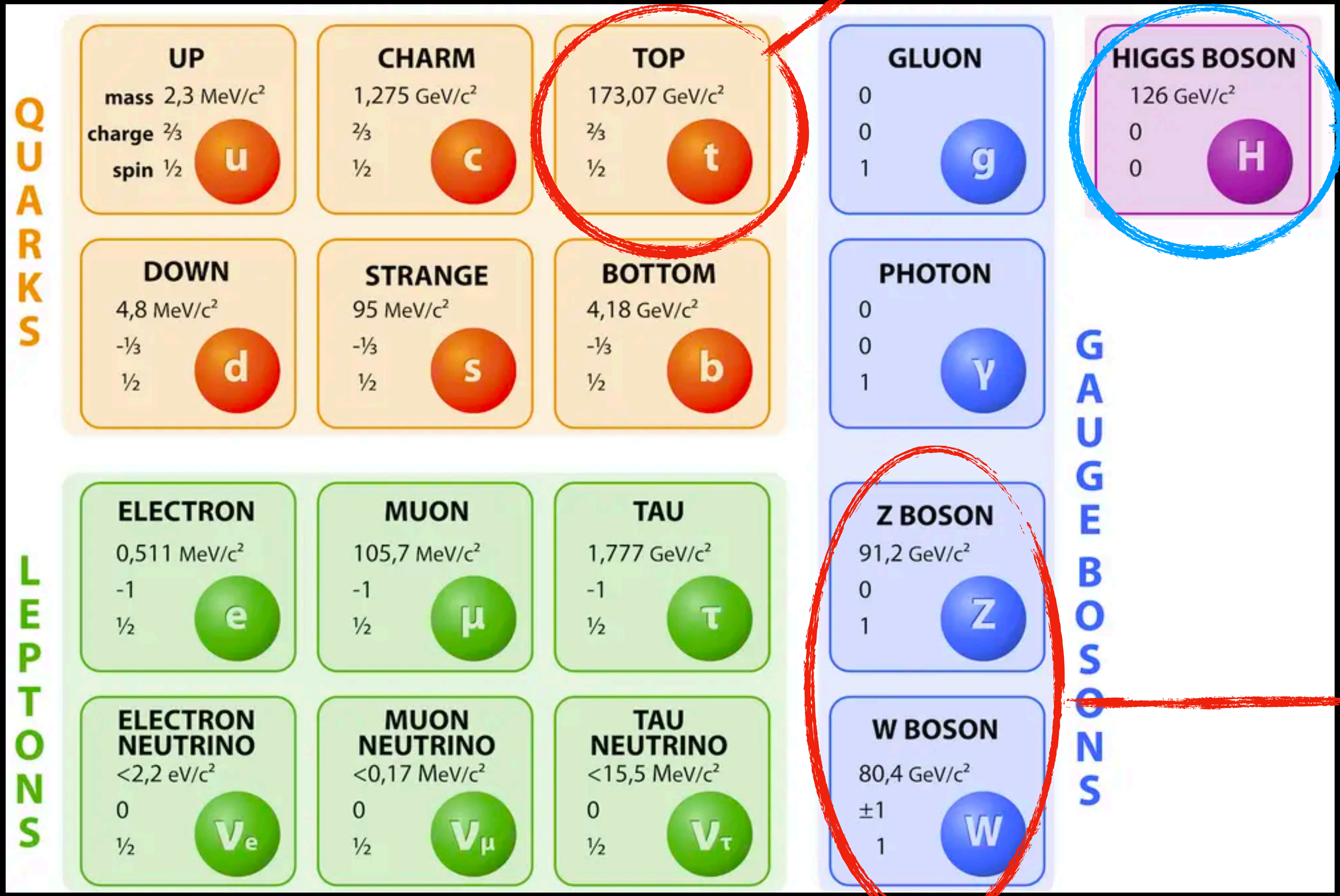
Collides with an atom in the atmosphere, creates new particles

Idea behind particle colliders: create the fast-moving particles in the lab

Then can control the collisions, and surround the collision points with detectors to see what is happening

Discoveries at particle colliders

Discovered in 1995 at Tevatron (Fermilab)

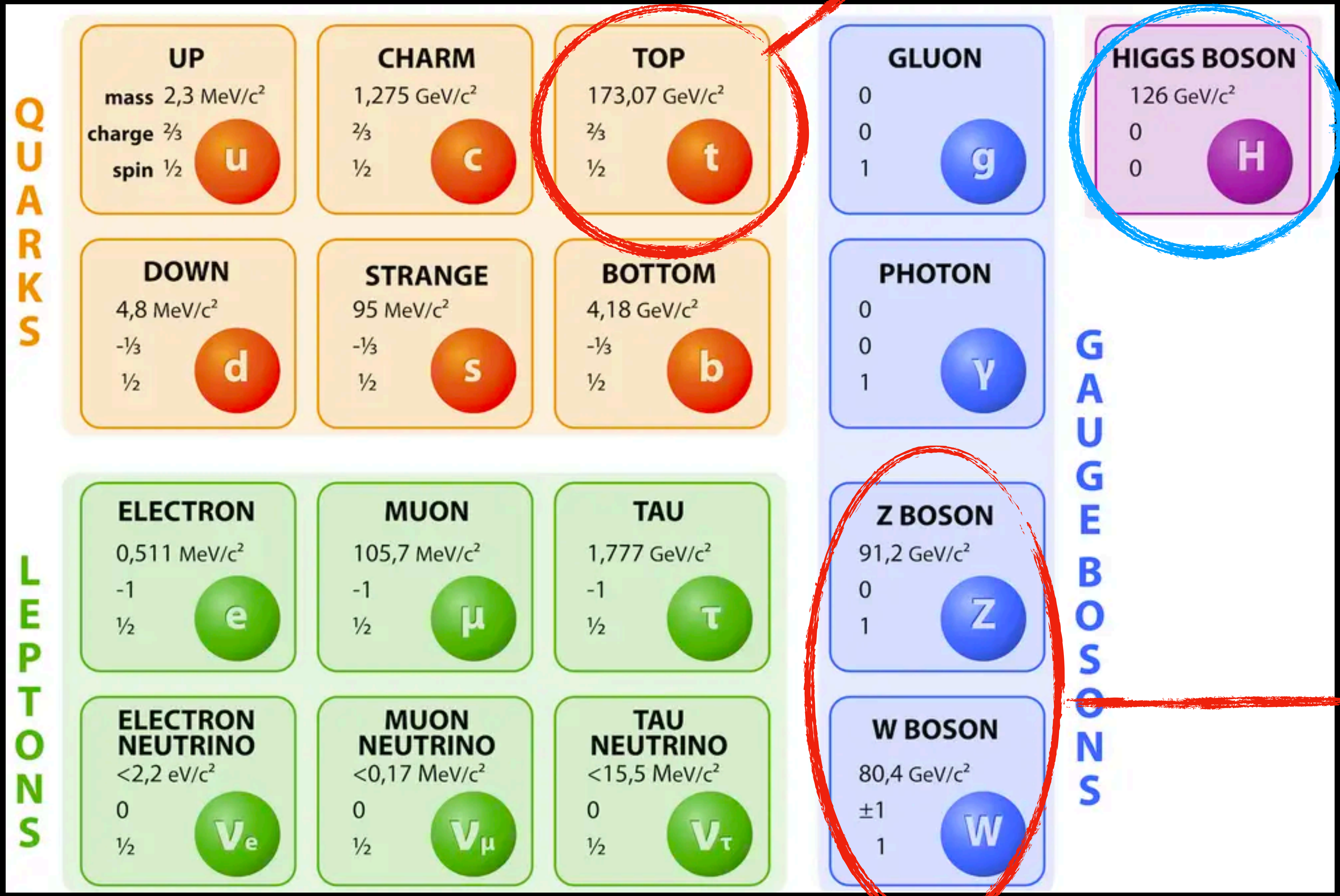


Last Standard Model particle to be found

Discovered in 1983 at Super Proton Synchrotron (CERN)

Discoveries at particle colliders

Discovered in 1995 at Tevatron (Fermilab)

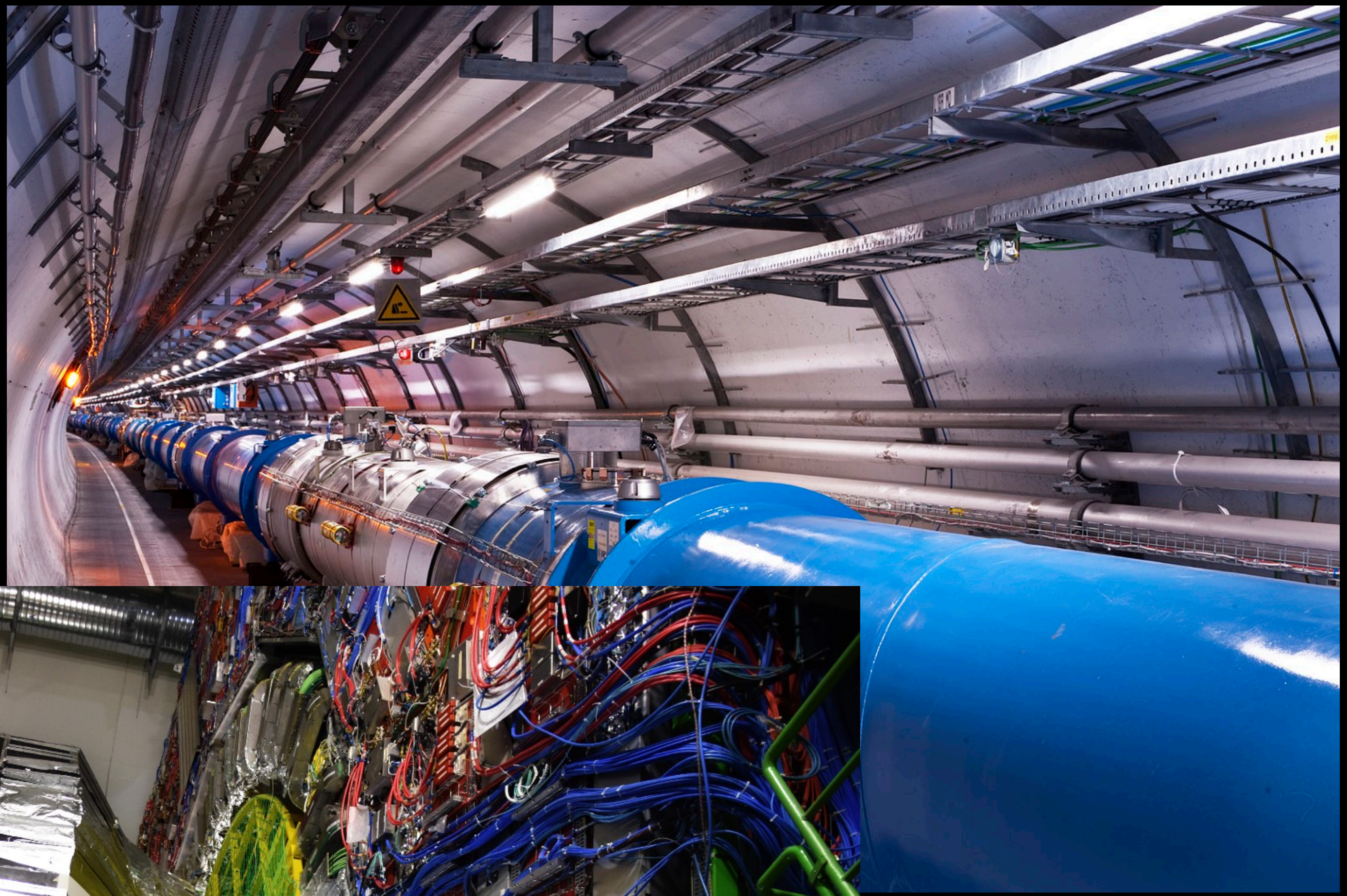


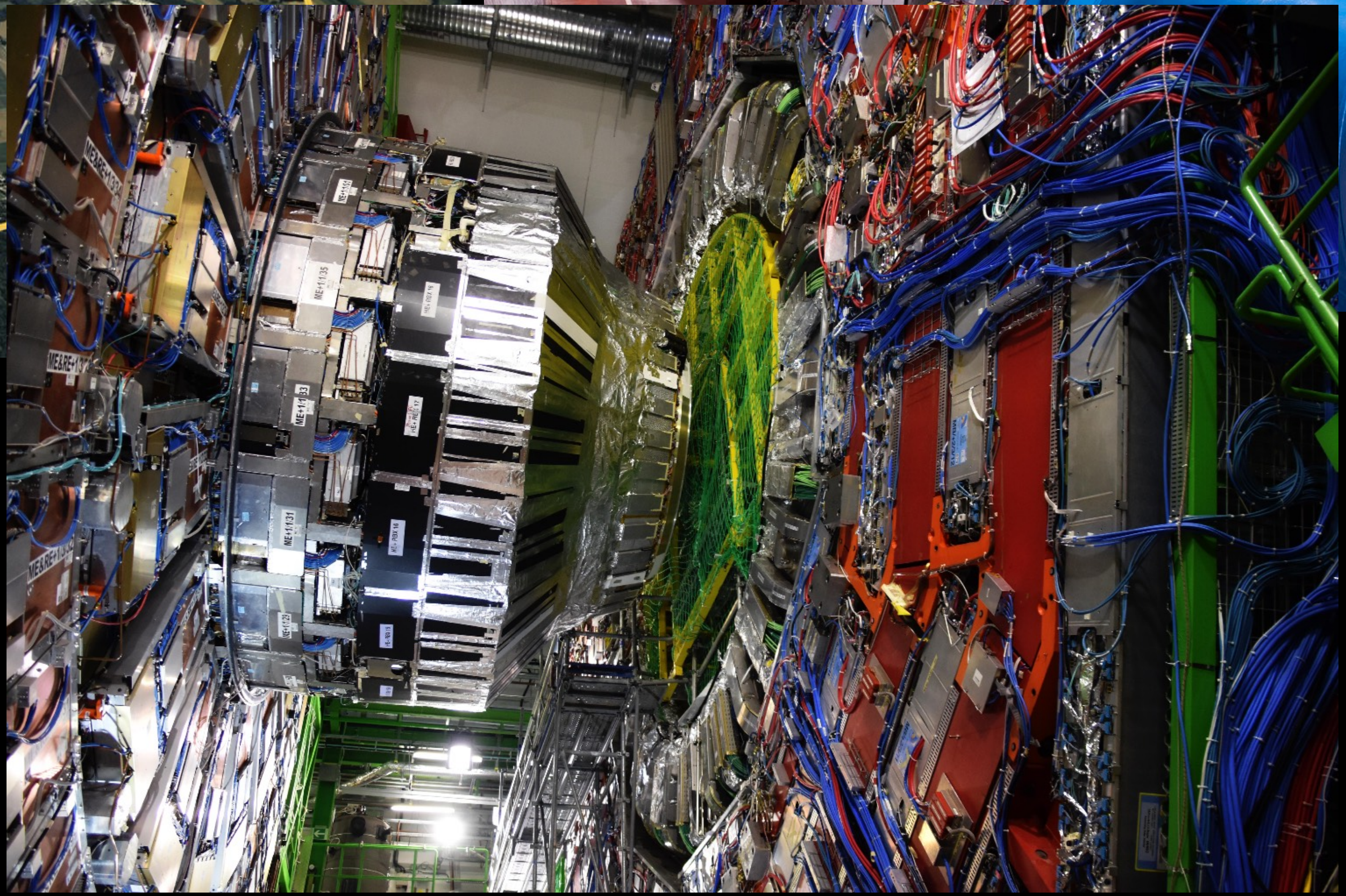
Last Standard Model particle to be found

Discovered in 1983 at Super Proton Synchrotron (CERN)

All these particles live for less than a billionth of a trillionth of a second

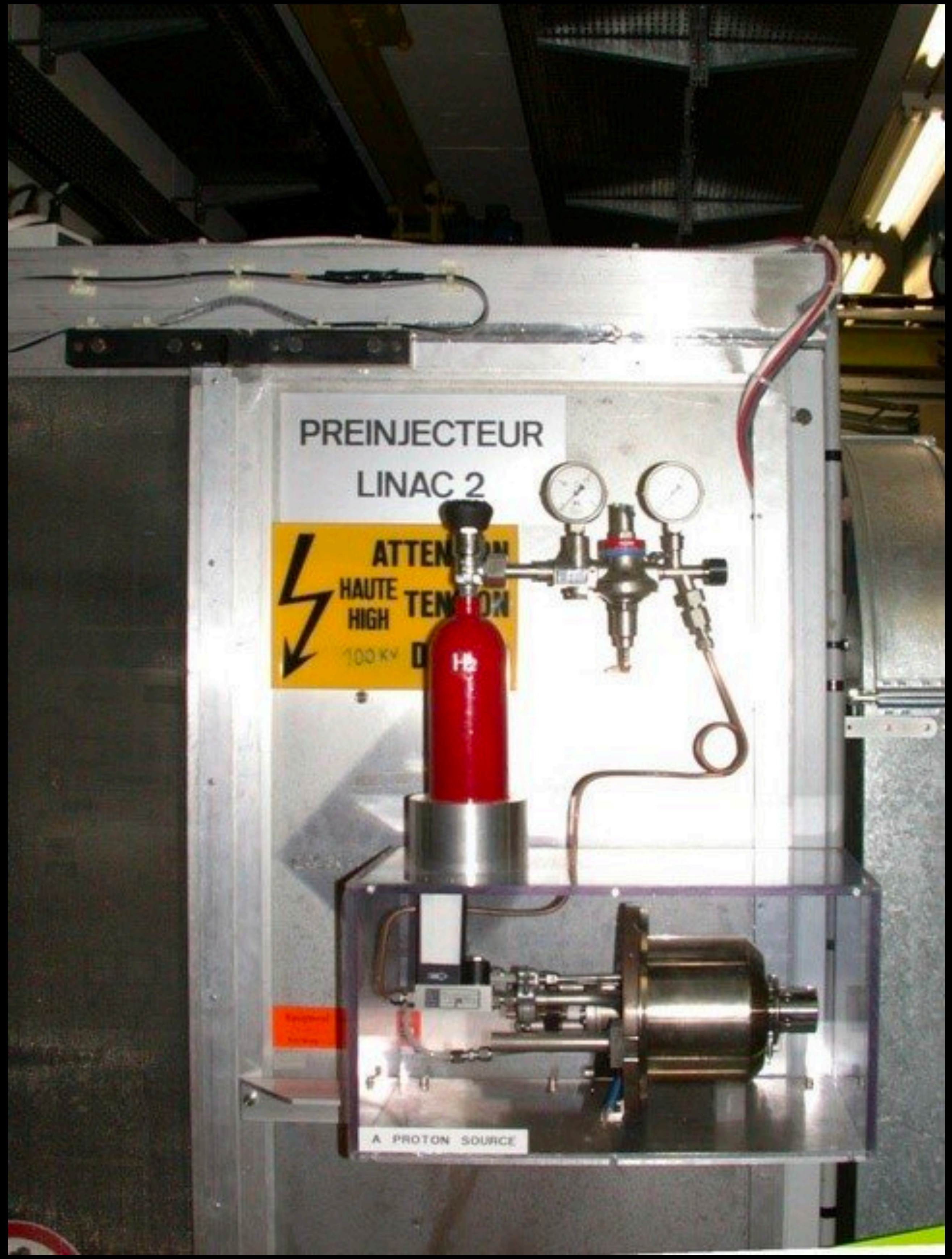
Particle physics now (or: how to kill a proton)

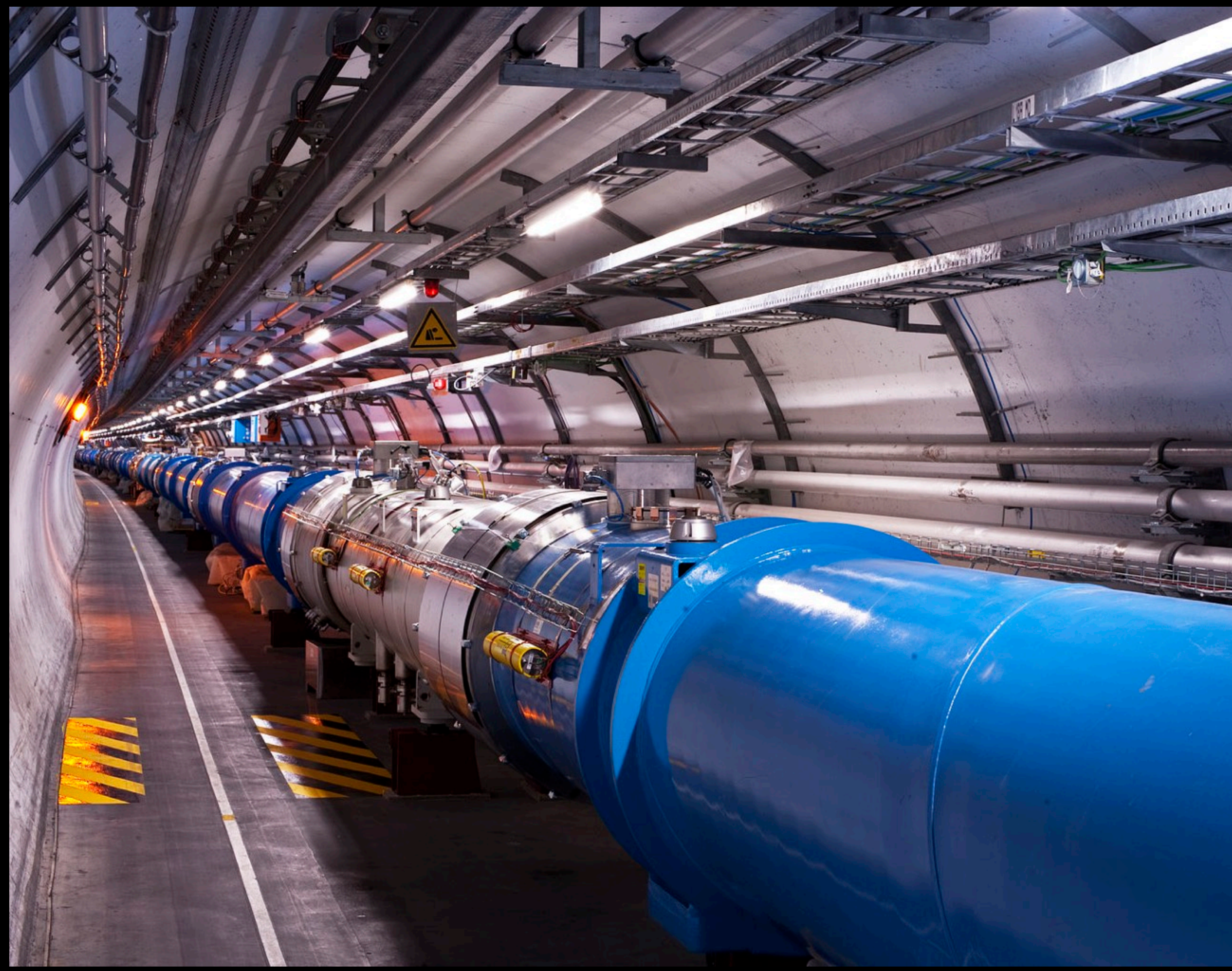




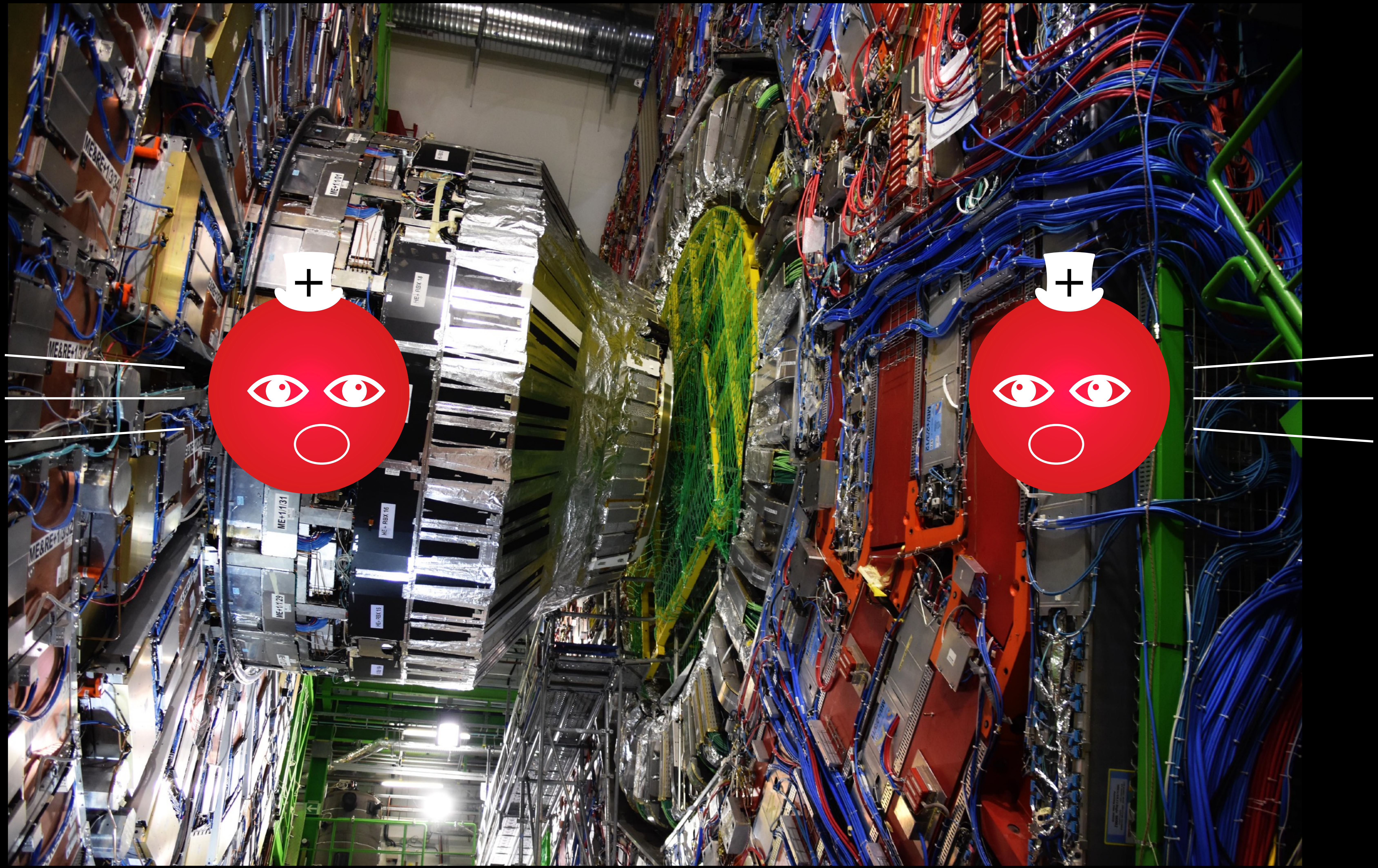
Large Hadron Collider
(LHC)

Particle physics now (or: how to kill a proton)





Particle physics now (or: how to kill a proton)

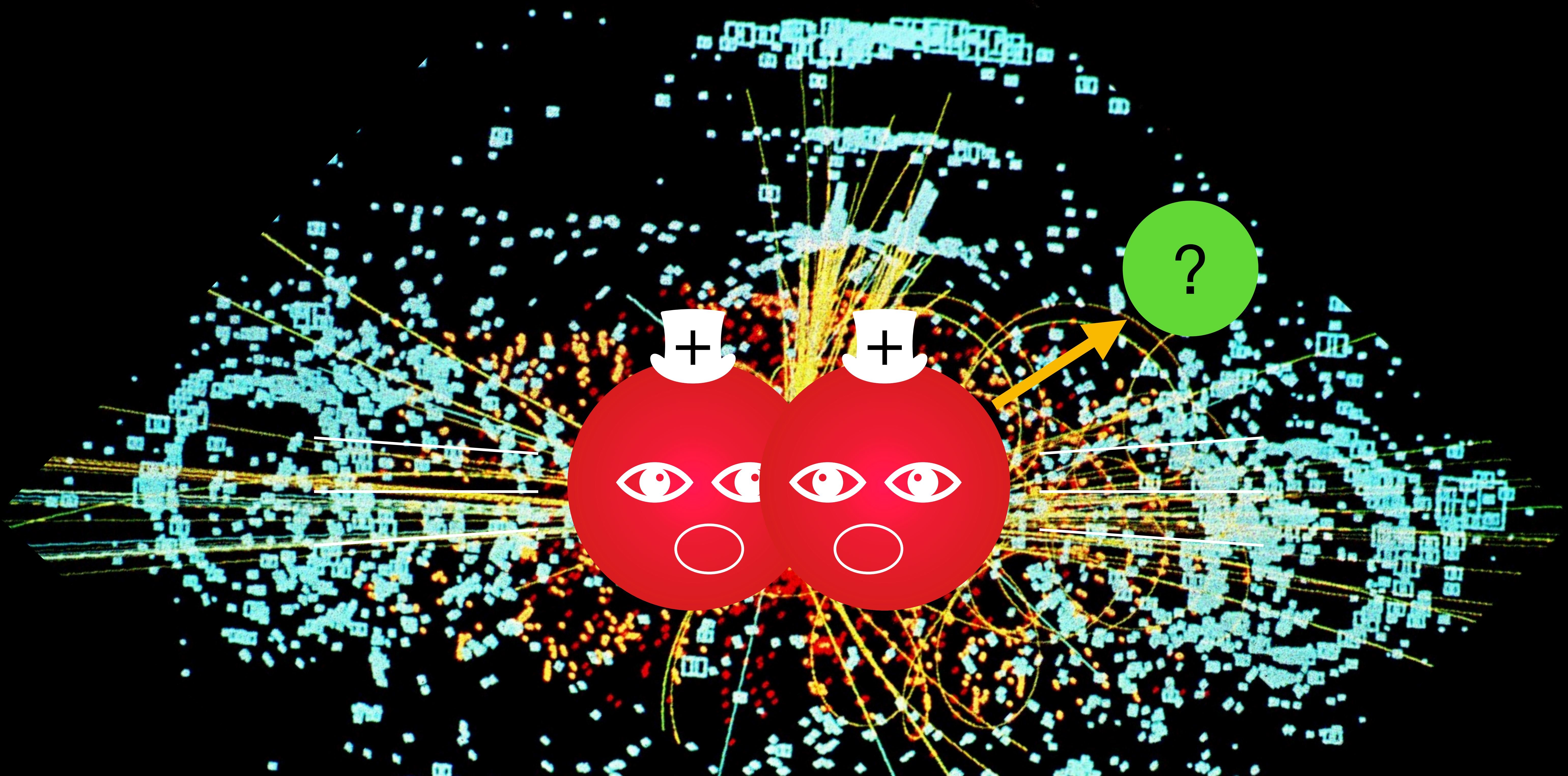


Matter from energy

The protons are carrying a LOT of kinetic energy

$$E = mc^2$$

Energy = mass x (speed of light)^2

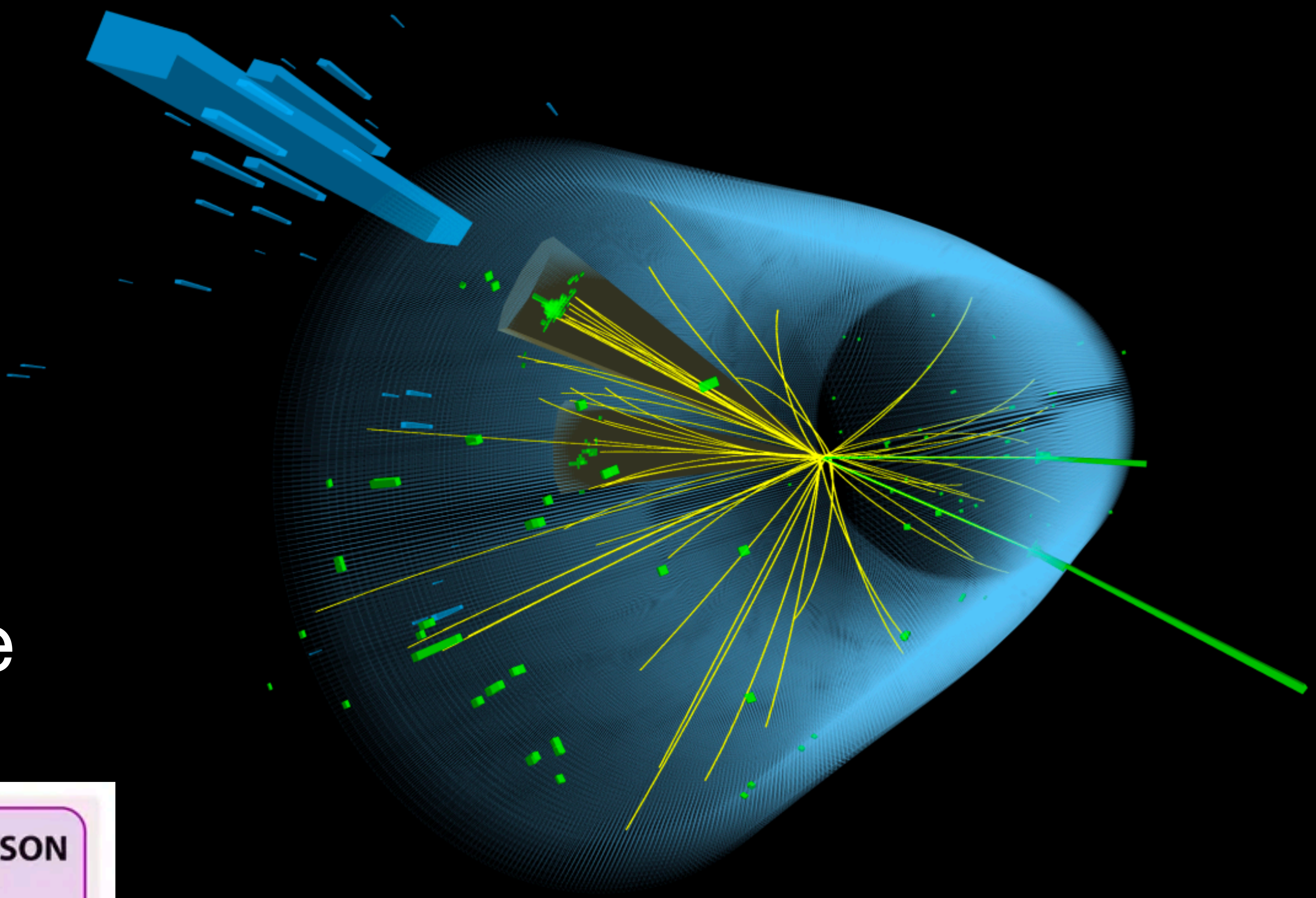


The discovery of the Higgs boson

The LHC was turned on in 2008

Soon, it became clear that a new particle was sometimes being created from the energy

By 2012, physicists were sure that this was the long-awaited Higgs boson

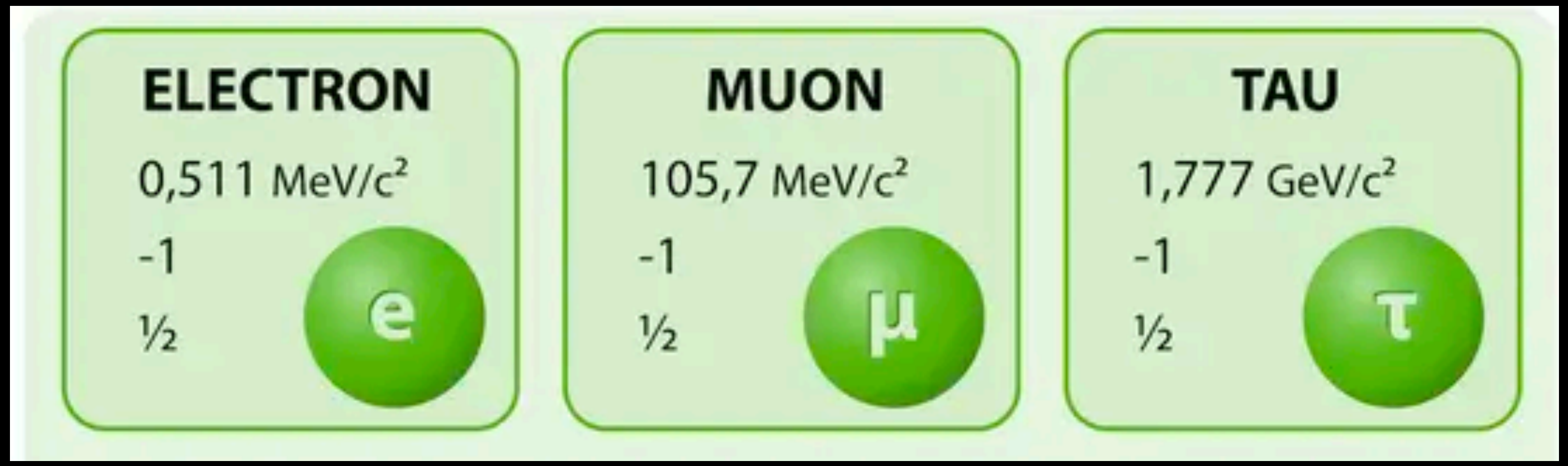


What's next?

We have reached the end of the Standard Model

Everything else is the unknown

"Dark matter"?!

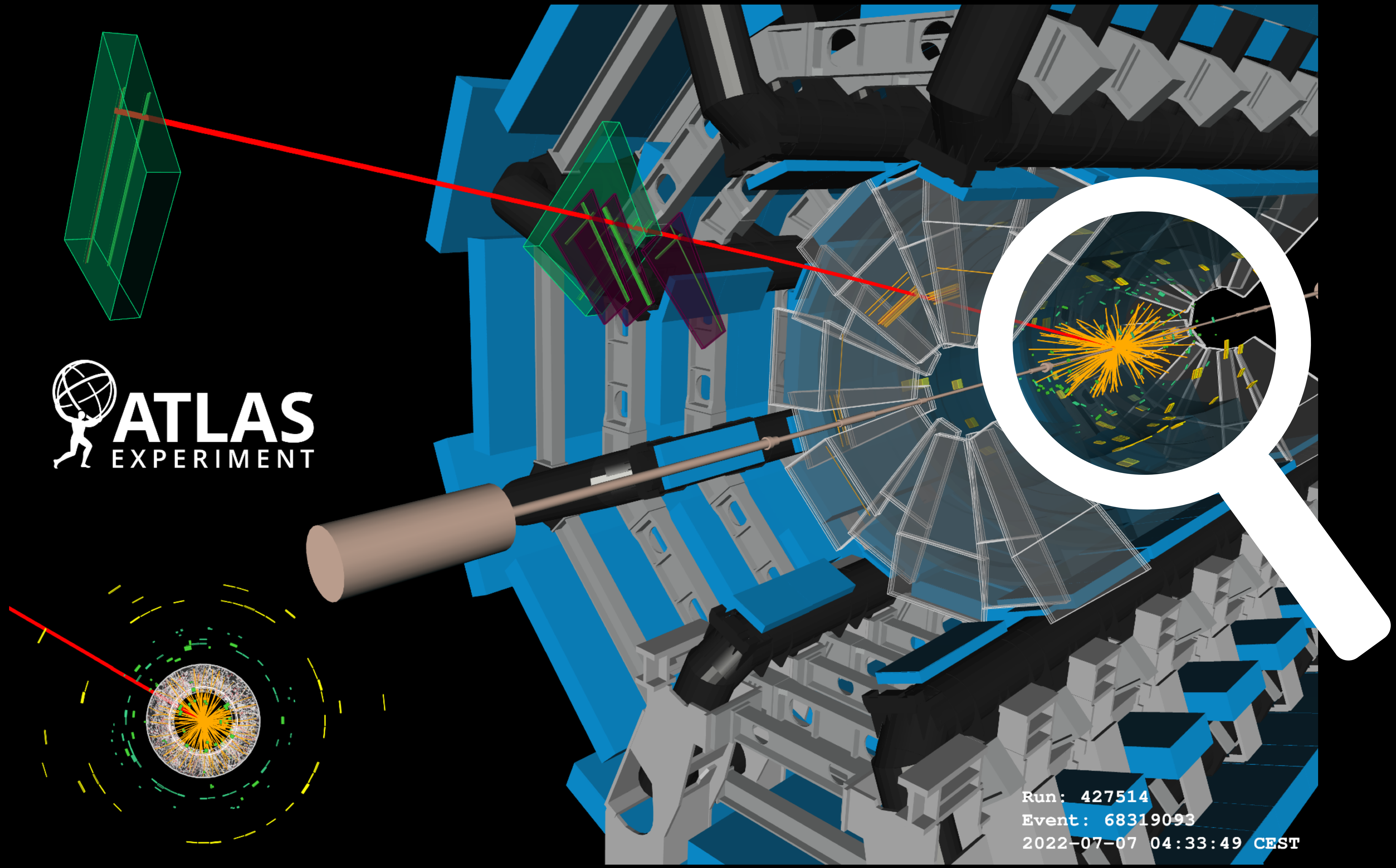


Why are there "extra" particles in the Standard Model?

Beyond the Standard Model

My research: how can new particles help to solve these puzzles?

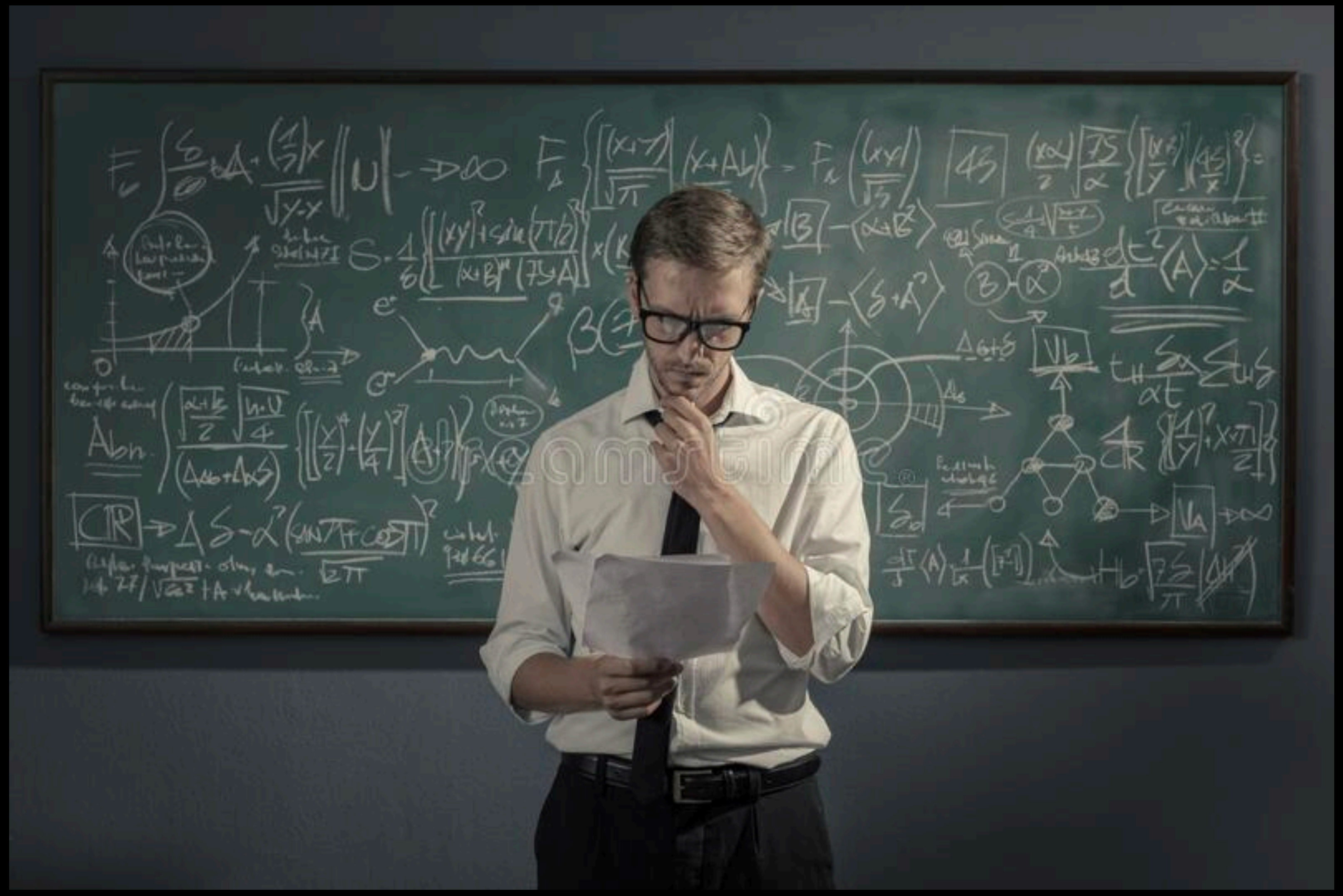
And how might we look for them at the LHC?



The life of a particle physicist

Stereotypes:

Works alone, antisocial, knows everything



Reality:

Constantly learning

Working in groups

Conferences, talks, discussion

Around the world with physics

CERN Summer Student Programme
CERN, Geneva
2 months during University

Kavli Institute of Theoretical Physics,
Santa Barbara, USA
6 months during PhD

Mainz, Germany (3 years)

Trieste, Italy (2 years)

CERN, Switzerland (1 year)

Thank you!

You can find me talking about physics on TikTok and Instagram
@sophiephysics