

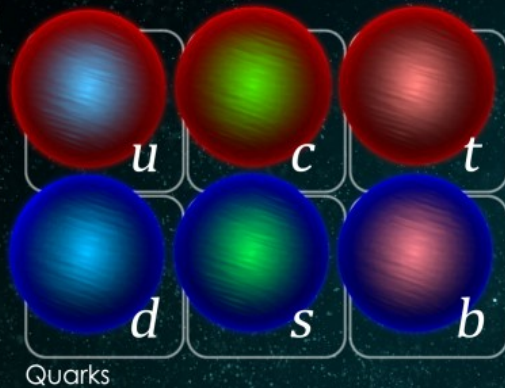
The Ghost Particle

Prof Steve Boyd,
Particle Physicist
University of Warwick

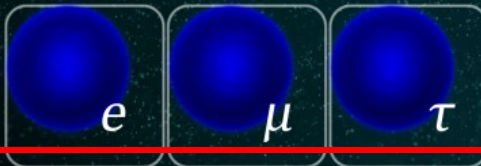


The Standard Model of Particle Physics

Quarks (Stuff)

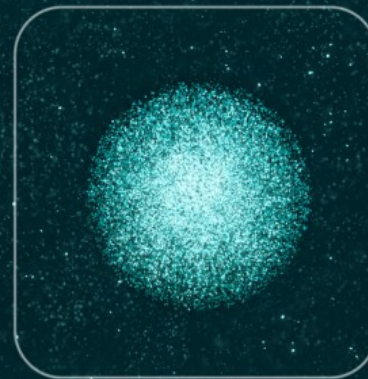


Leptons



Neutrinos

Higgs



Higgs boson

Bosons (forces)



Francis Halzen's IceCube Experiment



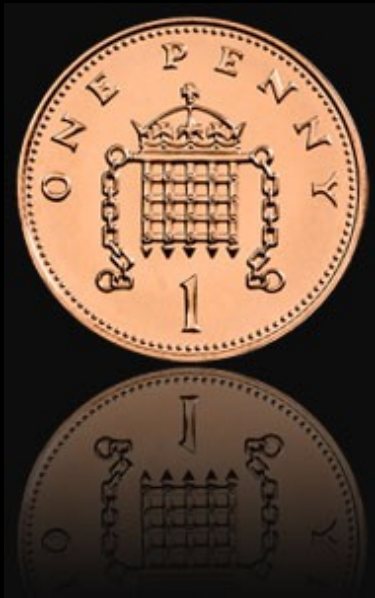
Three types (“flavours”) of neutrino



The second most common particle in the universe after light.

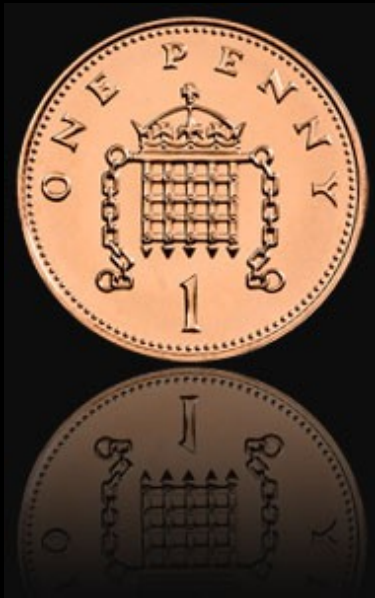
They are as close to nothing as stuff can get without actually being nothing....

If a neutrino weighs
as much as a penny...

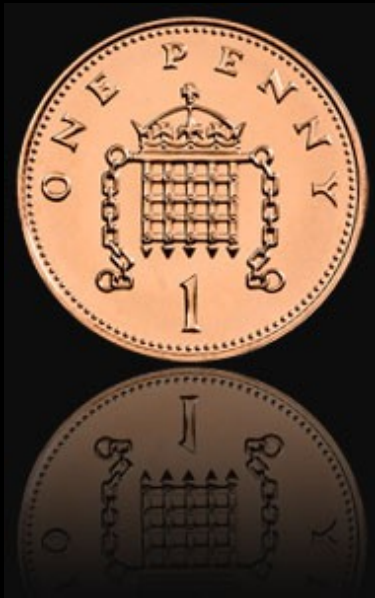


..then a nice cup of tea wei

If a neutrino weighed
a penny...



If a neutrino weighed
a penny...

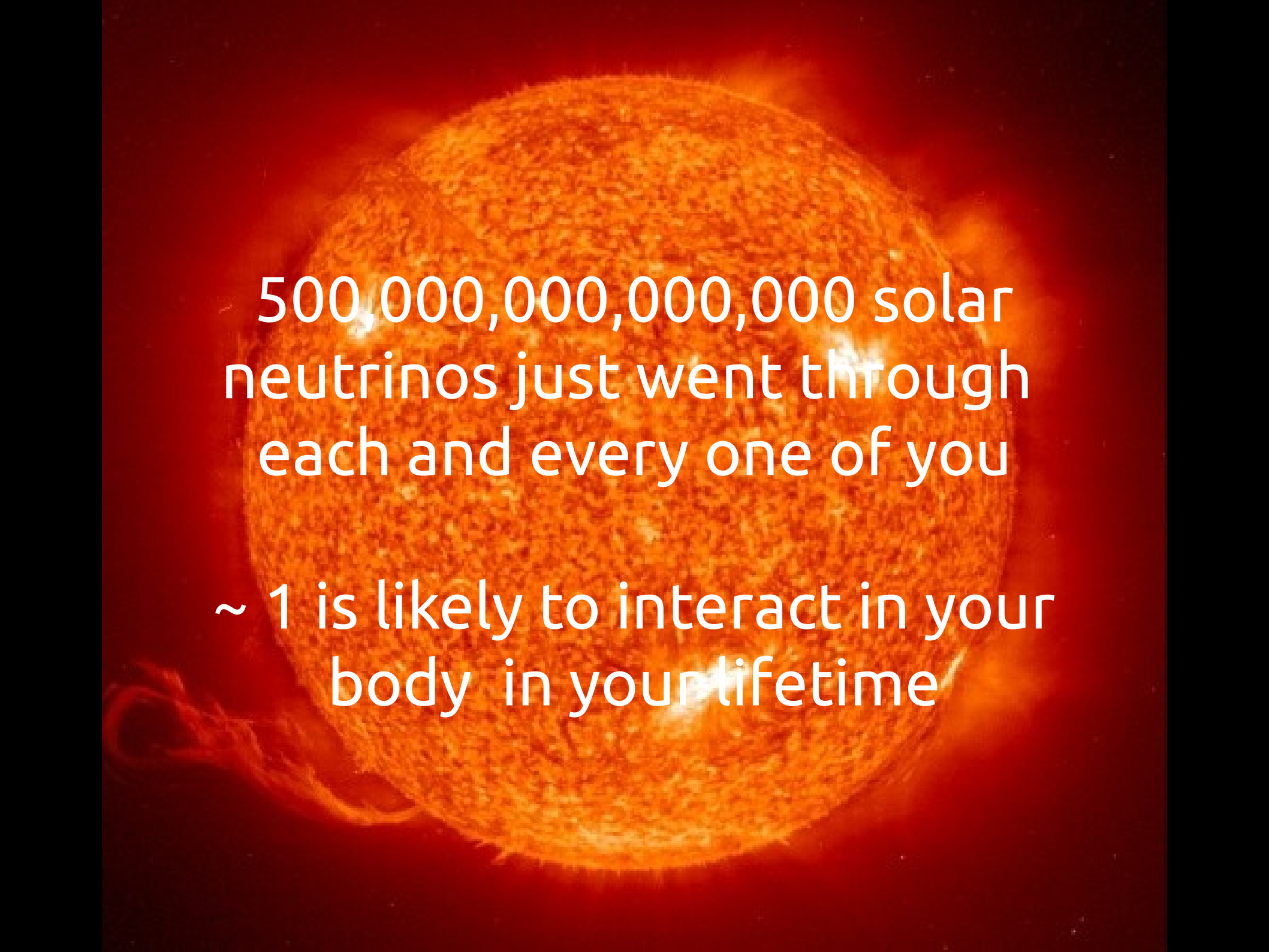


x 1,000,000

Neutrinos are very antisocial.

They refuse to talk to just about anything

A star is just a light mist to a neutrino



500,000,000,000,000 solar
neutrinos just went through
each and every one of you

~ 1 is likely to interact in your
body in your lifetime

So why are we interested in trying to study this most unsociable of particles?

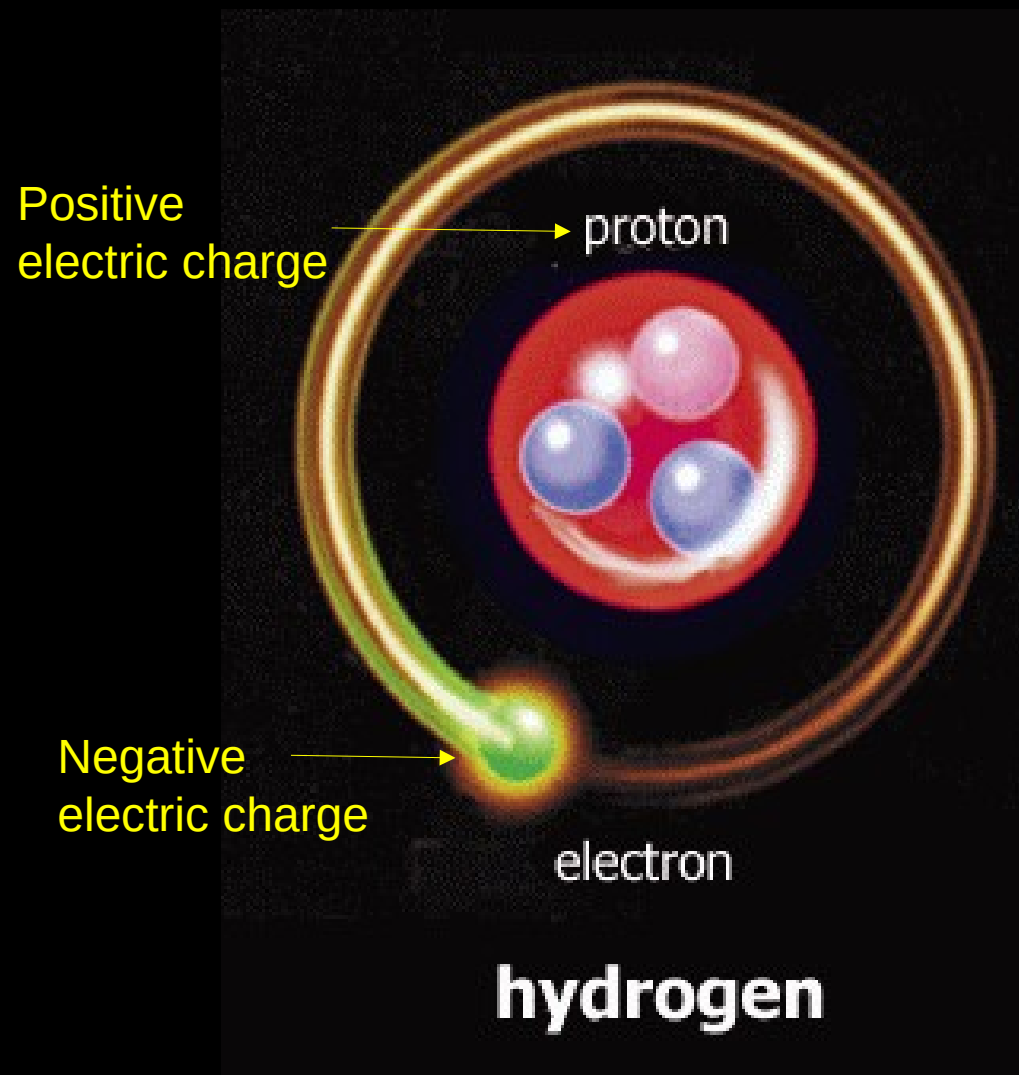




Where is all the antimatter?

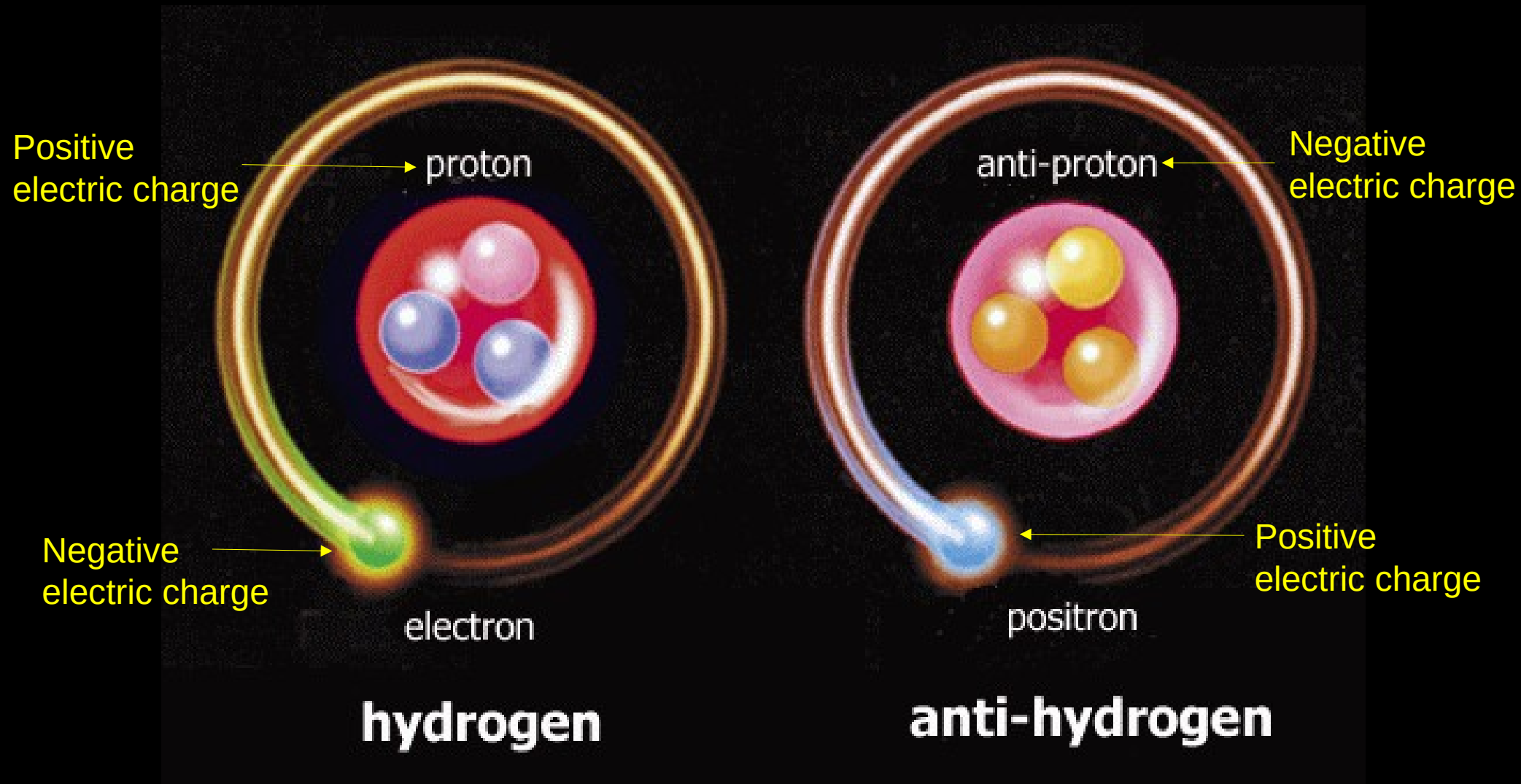


Matter



Matter

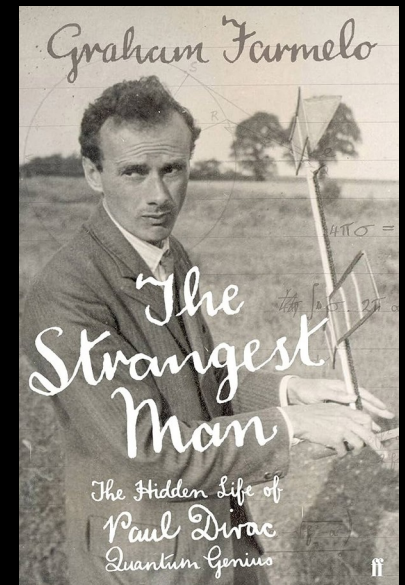
Antimatter





Antimatter was
proposed by
P.A.M Dirac in
1928

It was observed
experimentally in
1932

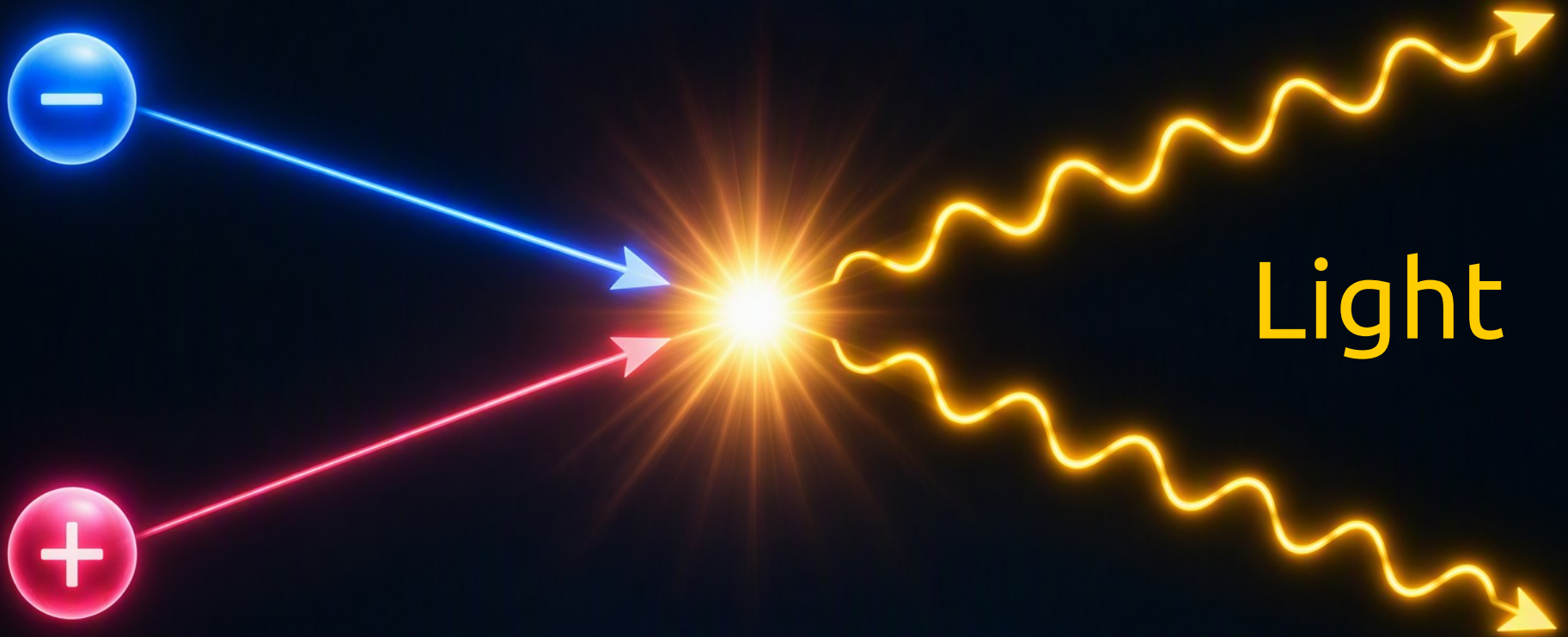


Matter



Antimatter

Light



Matter



Antimatter



Light

$$E = mc^2$$

$$c^2 \approx 9,000,000,000,000,000 \text{ m}^2\text{s}^{-2}$$

So, If you ever meet your anti-self, it is vitally important....

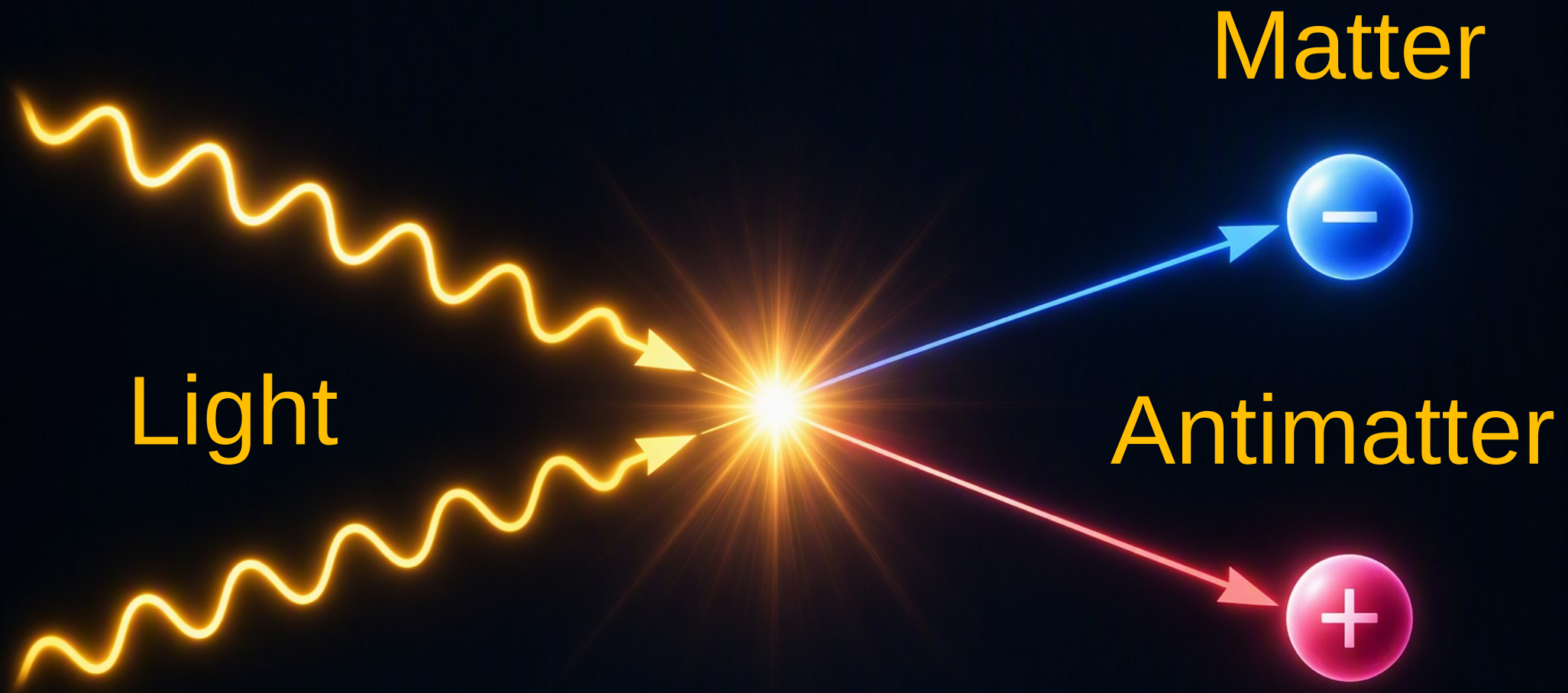


...never to shake hands



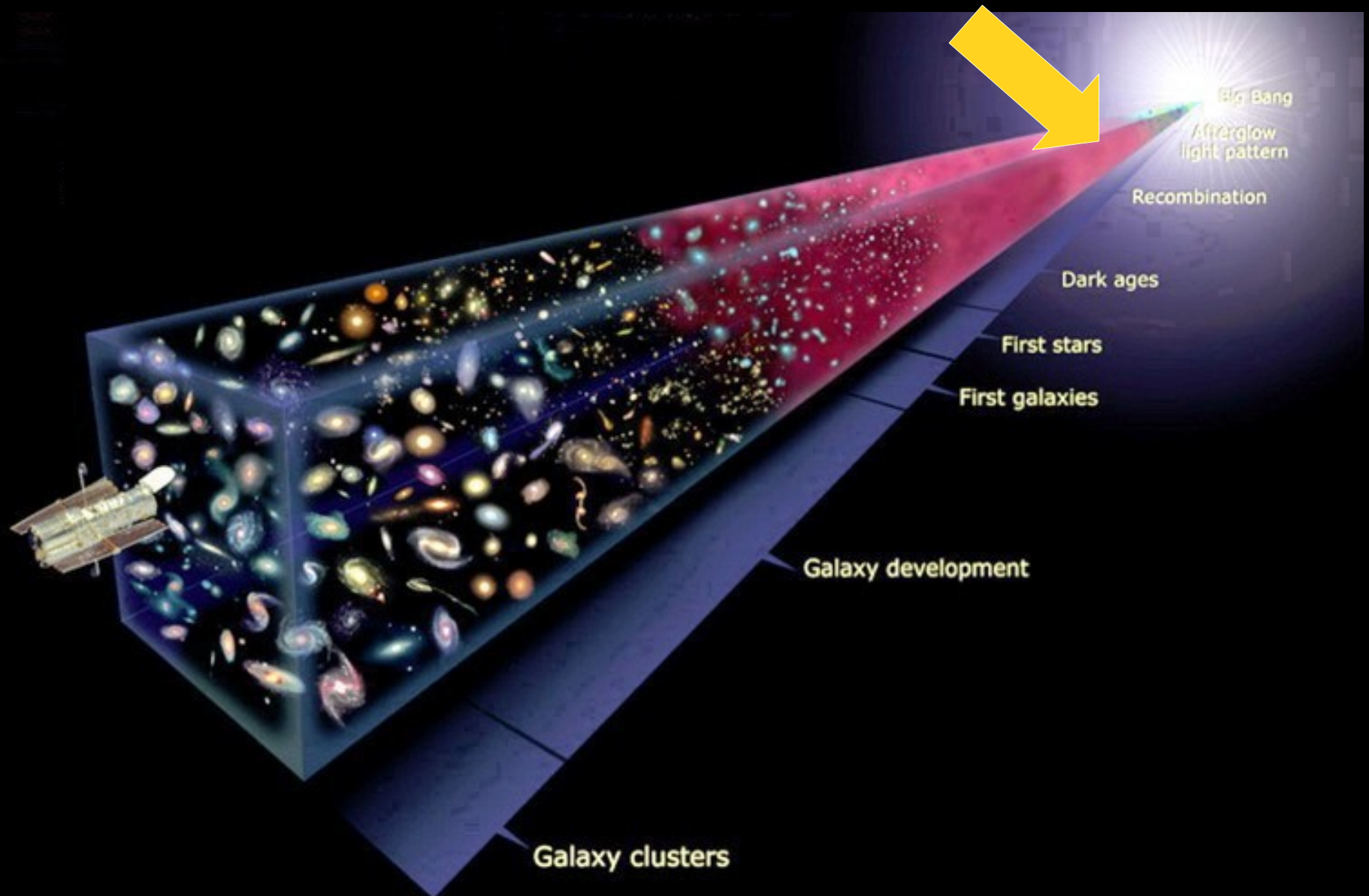
According to ChatGPT



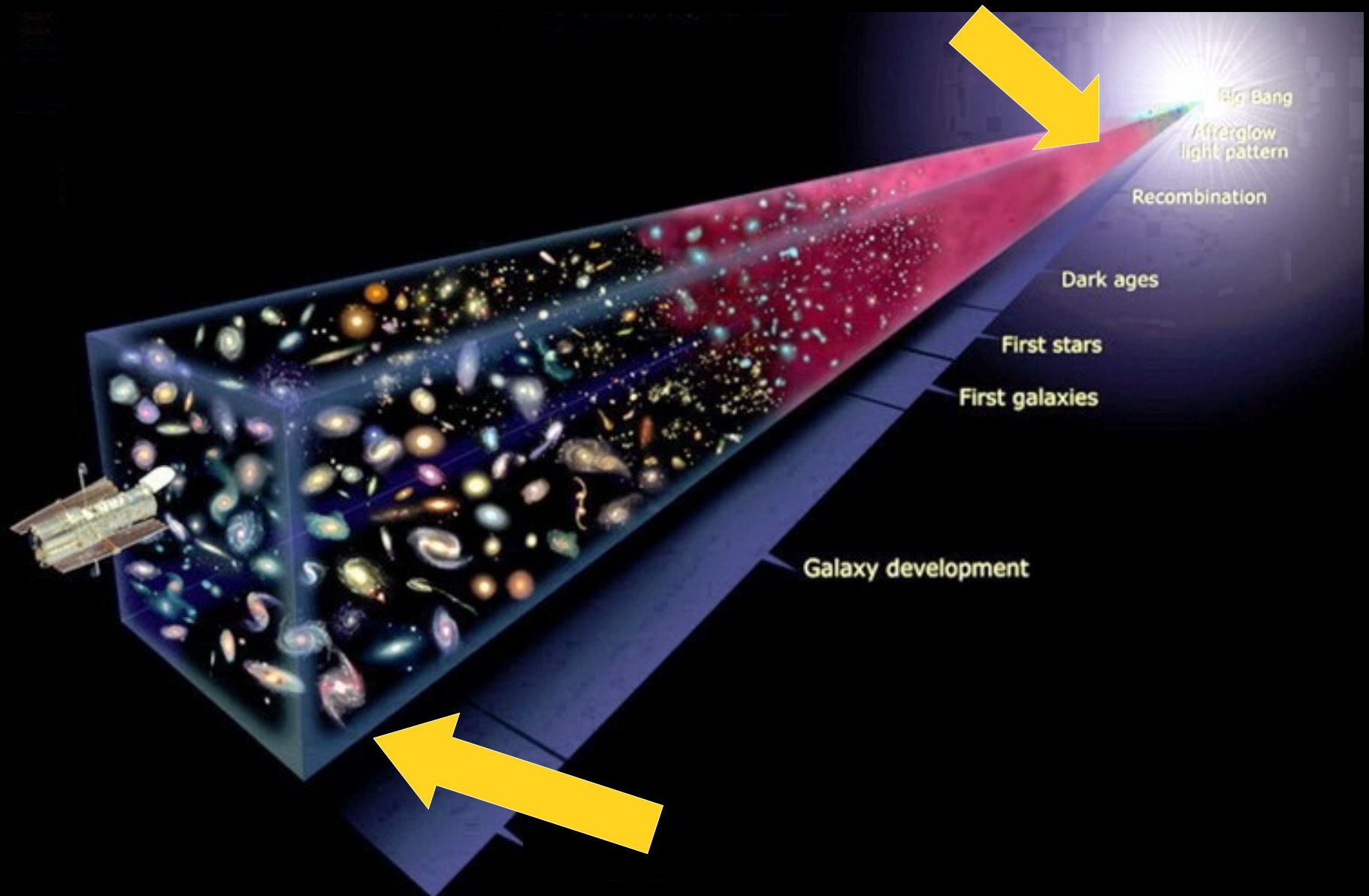


matter and antimatter are always
destroyed/created in pairs

Equal amounts of matter and antimatter



Equal amounts of
matter and antimatter



antimatter:matter = 1 : 10^9



Where did all the antimatter go?



An imbalance can occur if the laws of physics act differently on matter and antimatter.

So we need to study a process which can be measured using both matter and antimatter

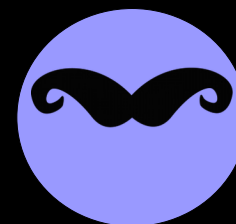
Neutrinos

Anti-neutrinos

Mario



Anti-Mario



Indiana

Anti-Indiana

Neutrinos are Masters of Disguise – they change their identity as they travel



Source

Detector

“Flavour Change”

How can we use this effect?

If matter and antimatter behave differently

$$Prob\left(\text{blue circle with mustache} \rightarrow \text{brown hat on green downward triangle}\right) \neq Prob\left(\text{blue circle with mustache} \rightarrow \text{brown hat on green upward triangle}\right) ?$$

An idea floating around suggests that, if this happens, then we may be able to explain the matter-antimatter imbalance and hence, why are able to exist





Hyper-Kamiokande Experiment





Hyper-Kamiokande Experiment



Image © 2008 TerraMetrics
Image NASA
Image © 2008 Digital Earth Technology

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Pointer 37°18'07.37" N

138°10'10.80" E

Streaming

100%

Eye alt 155.07 m



Hyper-Kamiokande Experiment



SuperKamiokande



JPARC

100%



Image © 2008 TerraMetrics

Image NASA

Image © 2008 Digital Earth Technology

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Hyper-Kamiokande Experiment



Kamioka



SuperKamiokande



JPARC

295 km

100%



Image © 2008 TerraMetrics

Image NASA

Image © 2008 Digital Earth Technology

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Hyper-Kamiokande Experiment



90% 



Super-Kamiokande



JPARC

10% 

295 km

100% 

Image © 2008 TerraMetrics

Image NASA

Image © 2008 Digital Earth Technology

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Hyper-Kamiokande Experiment



93% 

Super-Kamiokande

JPARC

7% 

295 km

100% 

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Image NASA

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Easy, right ???

Hyper-Kamiokande Experiment



Super Kamiokande

“Far” detector



JPARC

Neutrino beam

Tokai

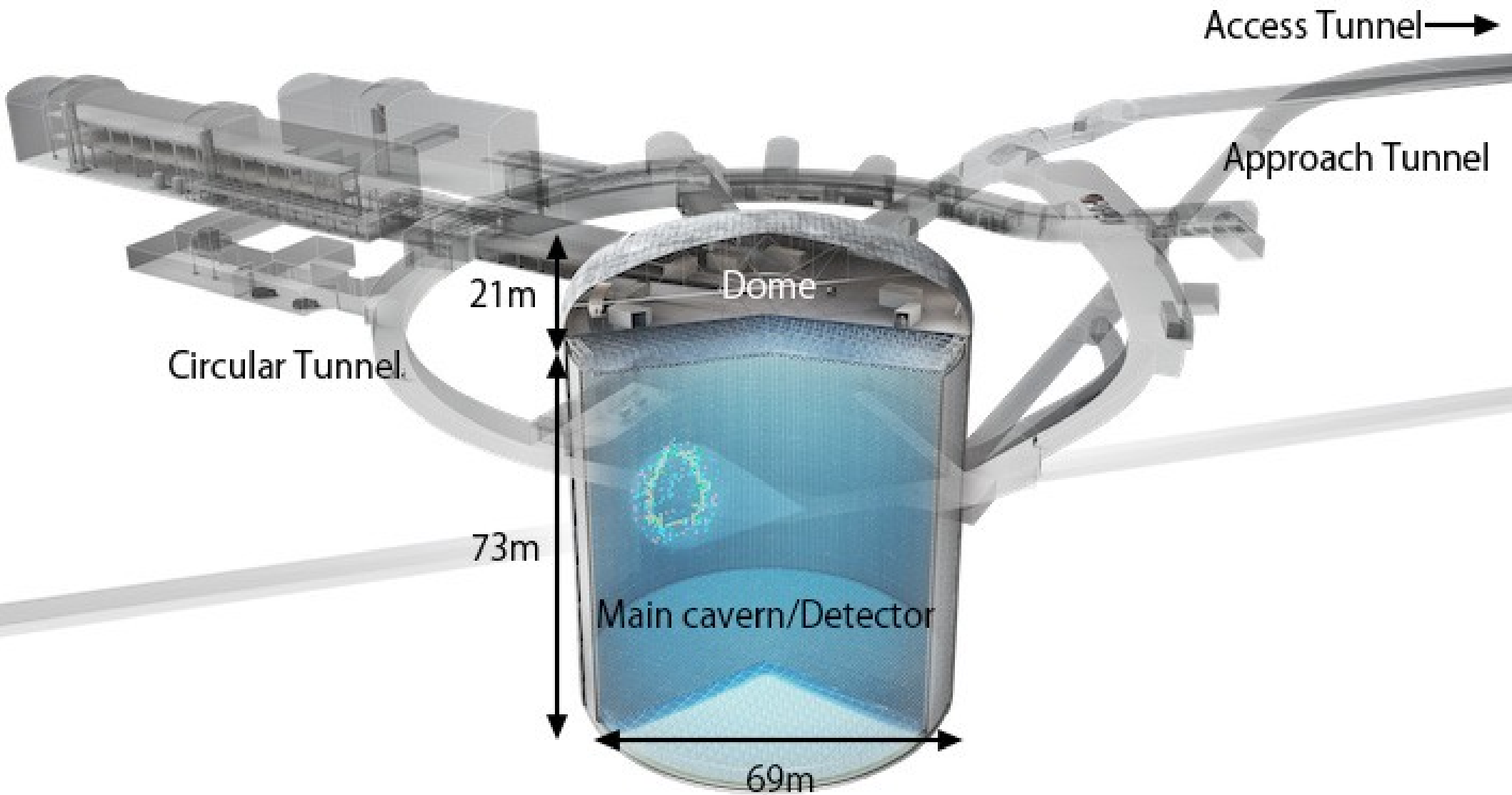
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Image NASA

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At the core of Mt Nijugo....



We are building a detector containing 200 kton of pure water



July '26



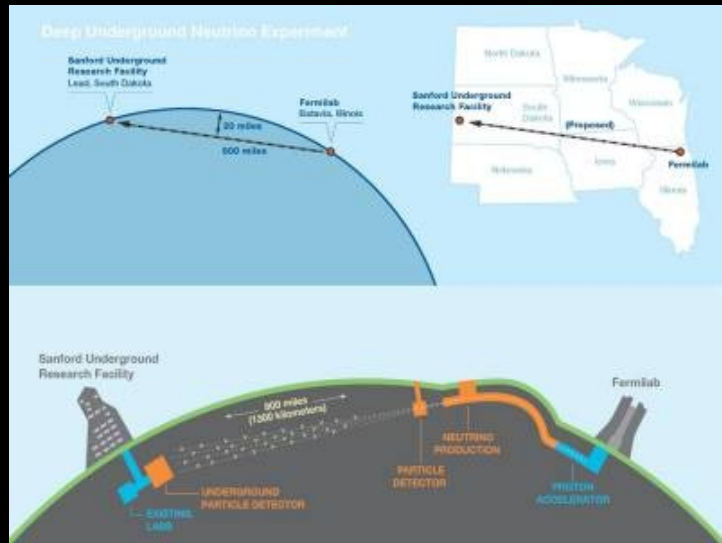
Why are we here?

- The Universe displays a matter-antimatter imbalance that we don't understand.
- This is the reason why there is stuff.
- The lightest, most numerous, least studiable and most grumpy particle in the universe, the neutrino, may just hold the key to understanding *why* the laws are different!
- Warwick are involved in new experiments now to find out
- Check back around 2030'ish

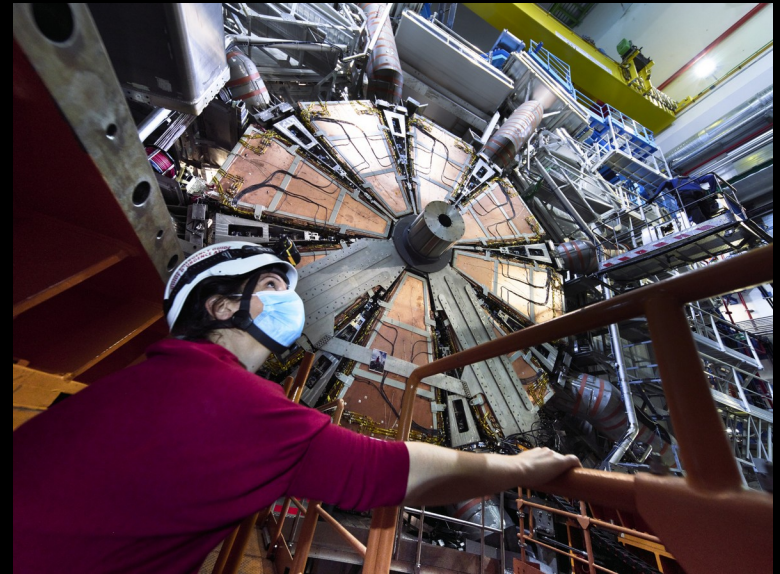
The background is a deep blue field filled with a complex network of thin, white, intersecting lines that resemble a web or a neural network. A prominent, bright white oval shape is centered in the lower half of the image. Overlaid on this is a solid yellow rectangle containing the text "Thank you" in a large, black, sans-serif font.

Thank you

Other research in EPP



DUNE in the USA

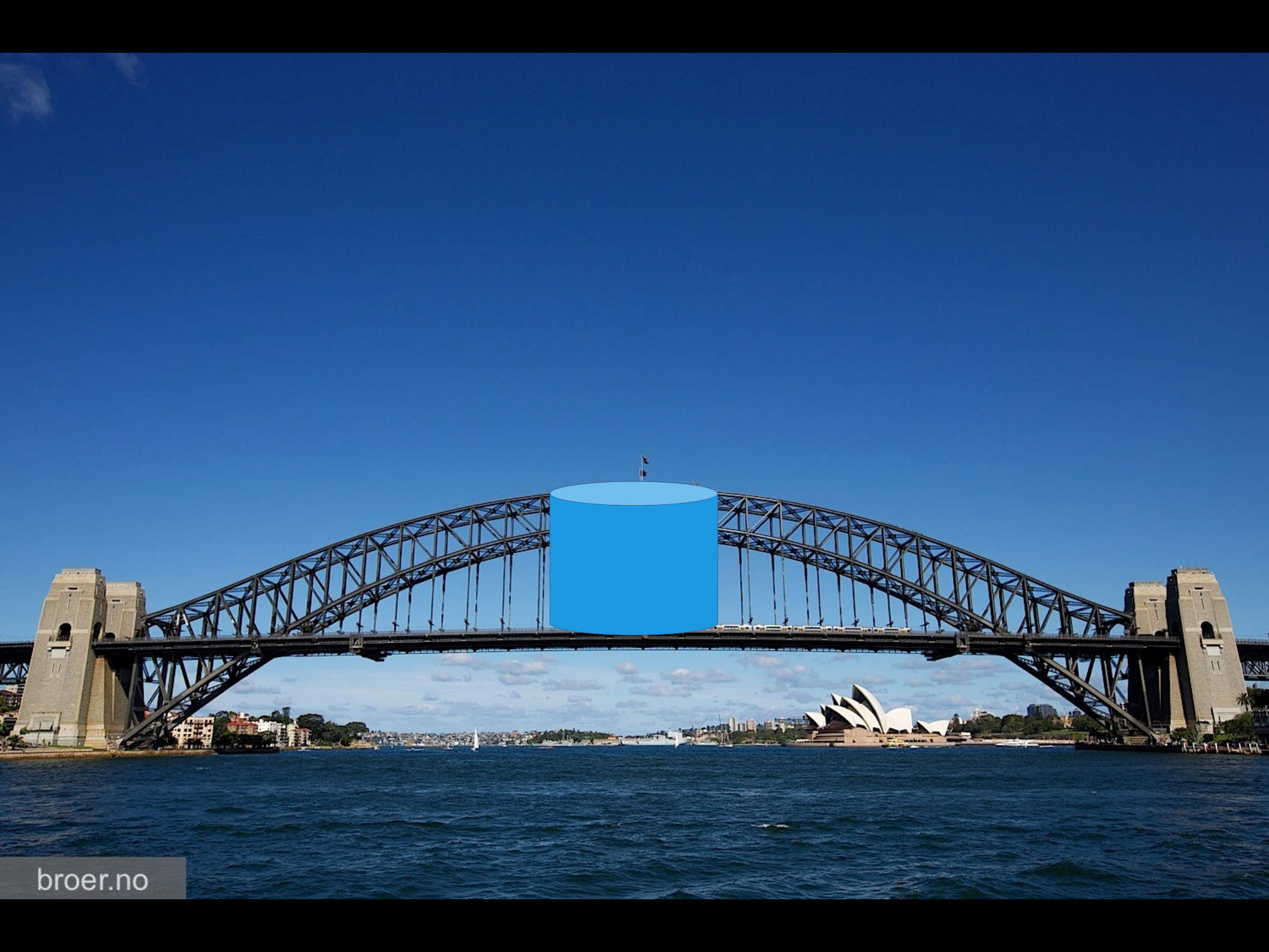


ATLAS @ CERN

LHCb @ CERN



...and many other programs and experiments.



Economic Impacts

- 5% of jobs in UK are in physics-based sectors
- Gross added value from physics sector was estimated to be 70 billion pounds in 2015
- Synergy between PP projects and industry – industry acquires added skills base for other applications
- Training - 50% of PP PhDs go into other sectors

Radioisotope production

Sensors for medical applications

High level computing for biological/climate modelling

Spin off tools for other science (e.g. DIAMOND)

Nuclear fusion research

Muon tomography in border security

Airport scanners

Rock Imaging

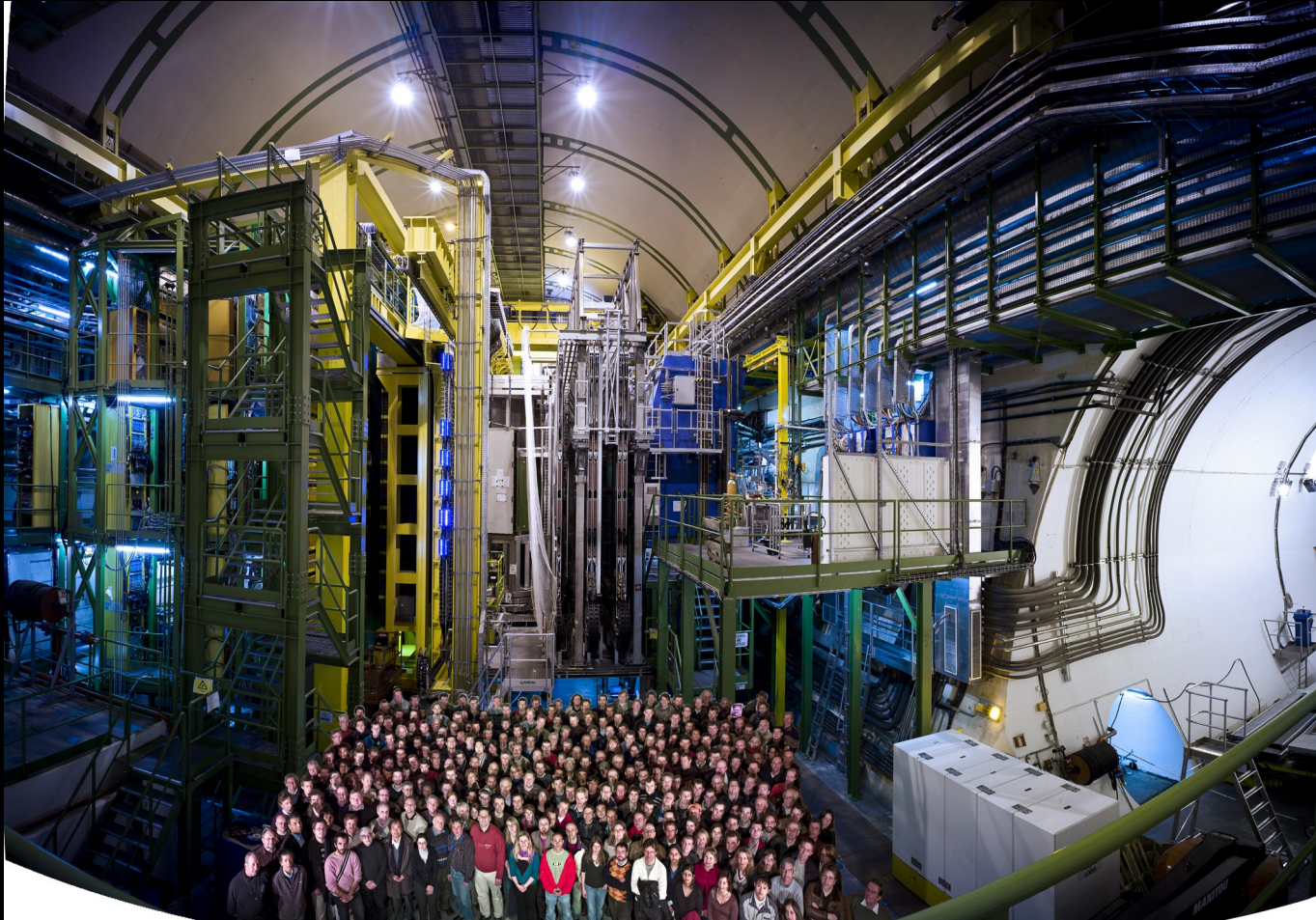
Cancer treatment using next gen cyclotrons
proton therapy

“...these kind of findings have implications that are not limited to the laboratory. They affect the whole of society — not only our economy, but our very view of life, our understanding of our relations with others, and our place in time.”

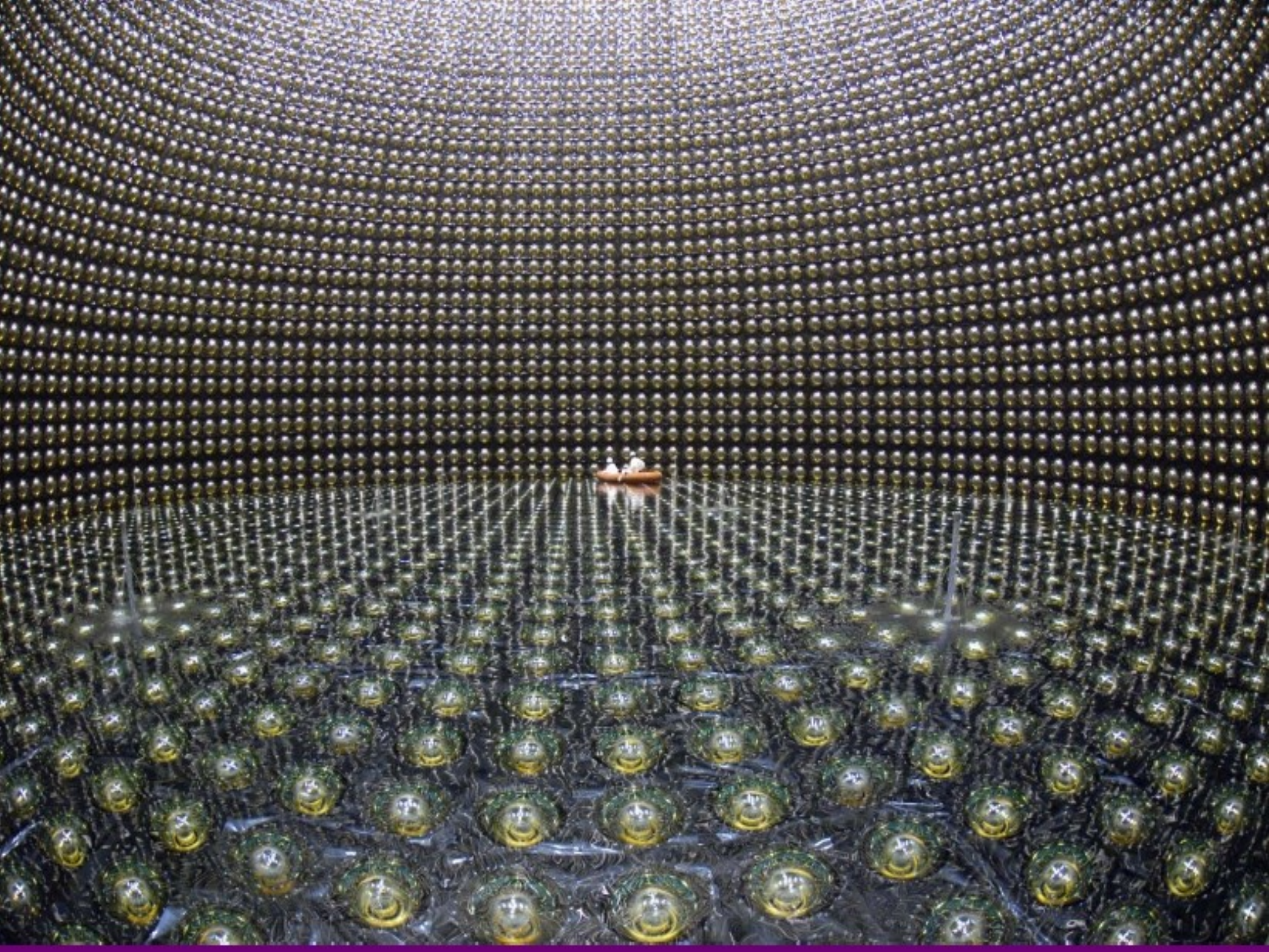
Bill Clinton

There *is* a difference between the physics of matter and antimatter. It's name is *CP Violation*

LHCb



The LHC will study this by looking differences between particles called B^0 and $\bar{B}^0$ mesons

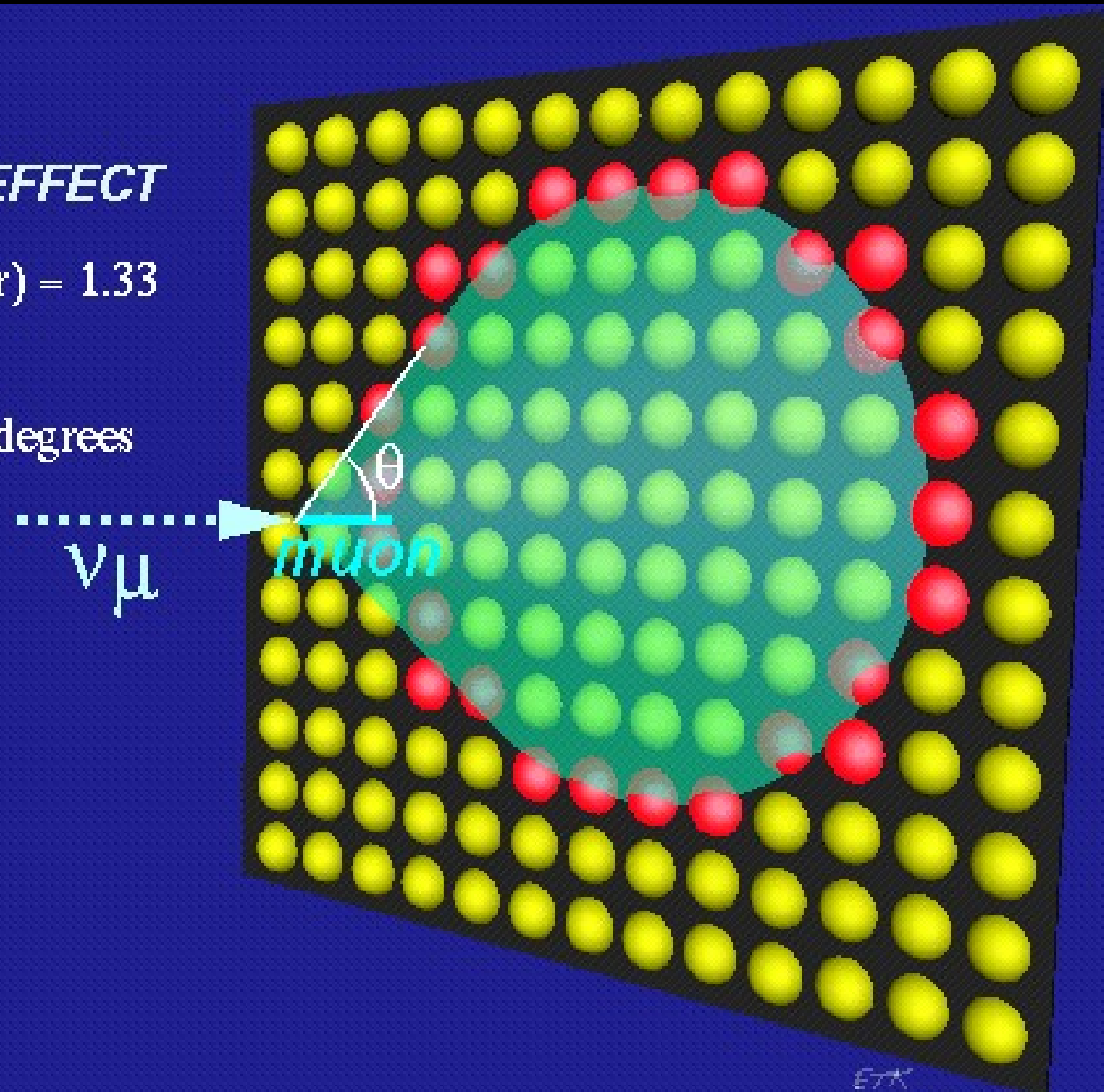


CHERENKOV EFFECT

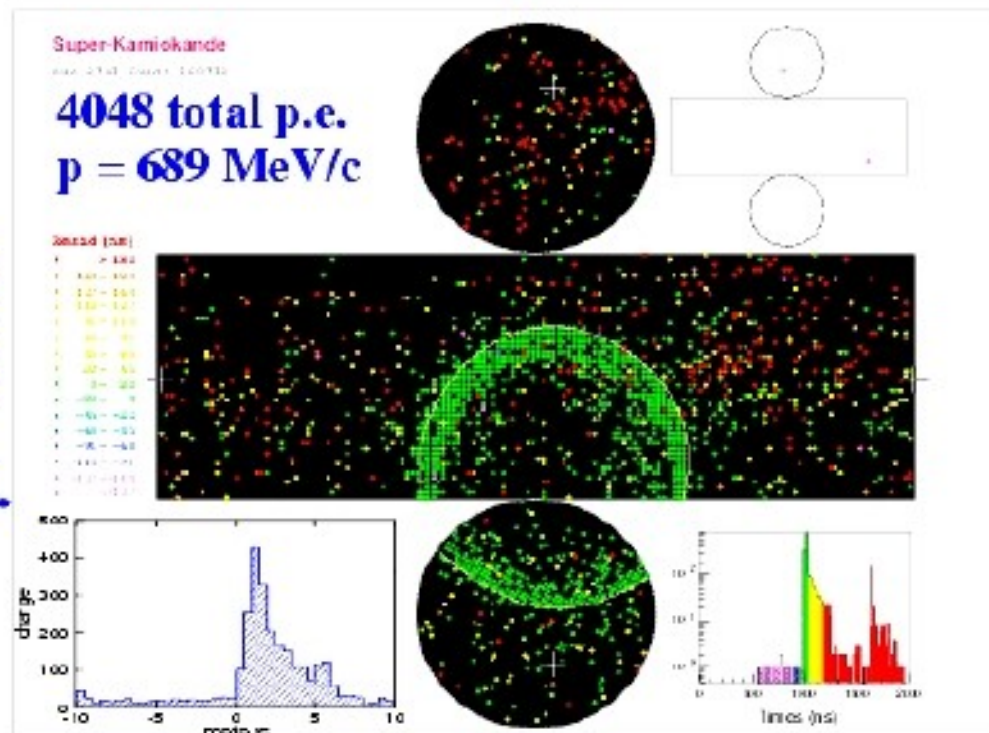
$$\beta = v/c \quad n(\text{water}) = 1.33$$

$$\cos \theta = 1/\beta n$$

$$\beta = 1 \quad \theta = 42 \text{ degrees}$$



μ -like



Muon-like : has a sharp edged ring and particle stopped in detector.