Higgs boson

The who, what and why of the journey to discovery…

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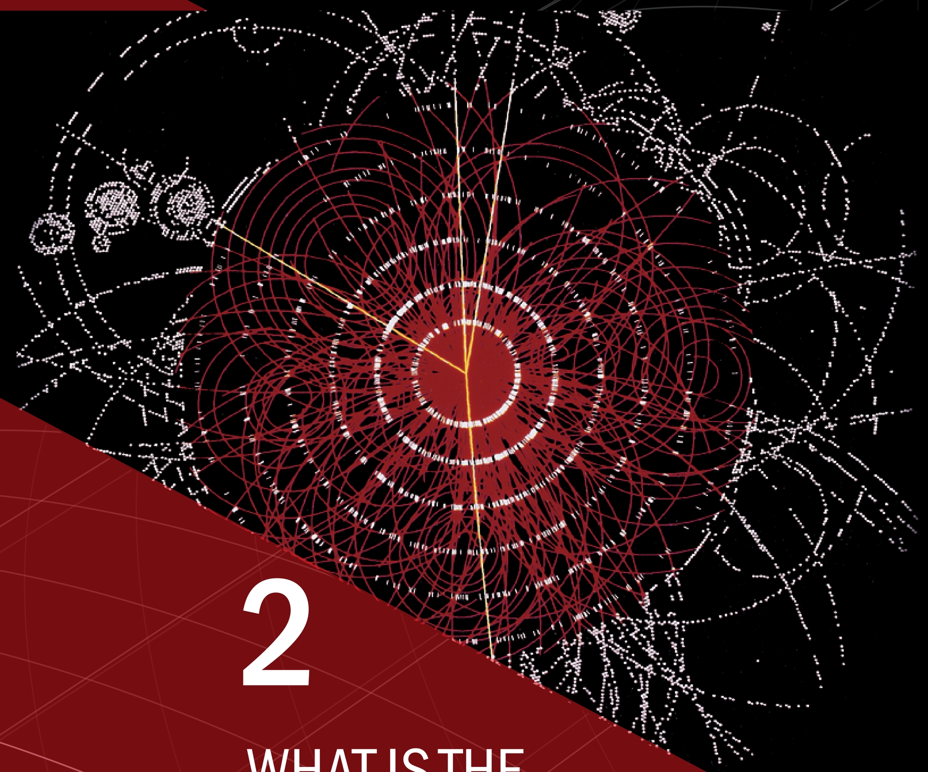

4 JULY 2012 WAS A TRULY HISTORIC DAY FOR SCIENCE

The elusive Higgs boson seemed to be finally found when a Higgs-like particle was announced as a formal discovery at CERN (the European Organization for Nuclear Research).

This announcement marked the completion of a journey spanning 48 years and extending from the theoretical postulation of the particle through to the construction of the most complicated experimental machine in history to find it.

2

WHAT IS THE HIGGS BOSON?

The Higgs boson has captured the minds of the world, but what exactly is this particle?

Despite being mistakenly referred to as "the God particle" – it doesn't tell us anything about how the universe came into being – the Higgs boson gives mass to the other known fundamental particles, which taken together form the "Standard Model", which is a mathematical description of the particles and forces of the universe at the most fundamental level.

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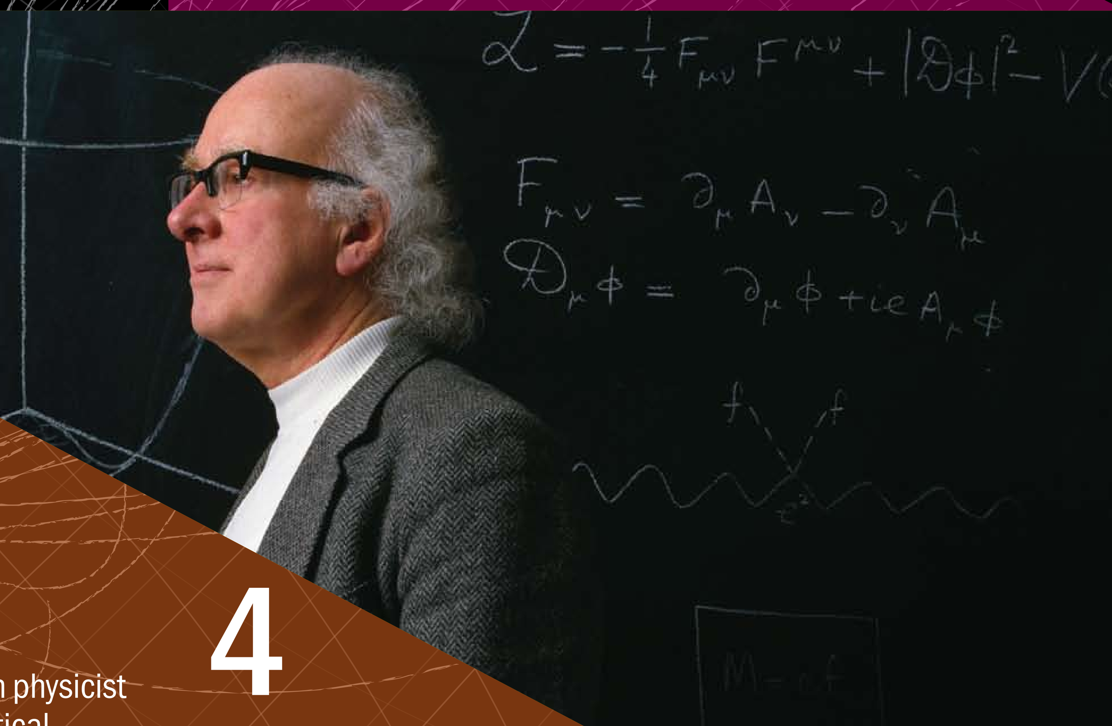

THE HIGGS BOSON THEORISTS

The concept of the Higgs boson was born in 1964 when a series of seminal papers by several authors were published, all independently describing very similar mechanisms for the existence of the property of mass for the fundamental particles.

The authors were the theoretical physicists Kibble, Guralnik, Hagen, Englert, Brout and Higgs (whose name became synonymous with the theory).

Peter Higgs is a British physicist who worked in theoretical particle physics at the University of Edinburgh. The prediction of the Higgs boson is his most well known work, prompting the decades-long search for the postulated particle, whose discovery Higgs was unsure he would see in his lifetime.

On 4 July 2012, the discovery of a new particle was announced in front of an emotional Higgs.

4

THE SEARCH FOR THE HIGGS BOSON

The prediction of the Higgs boson stimulated many experimental searches for the particle.

The Large Hadron Collider (the machine constructed at CERN that discovered a Higgs-like particle) is the latest incarnation of the large particle colliders that carry out experiments at unimaginably small scales.

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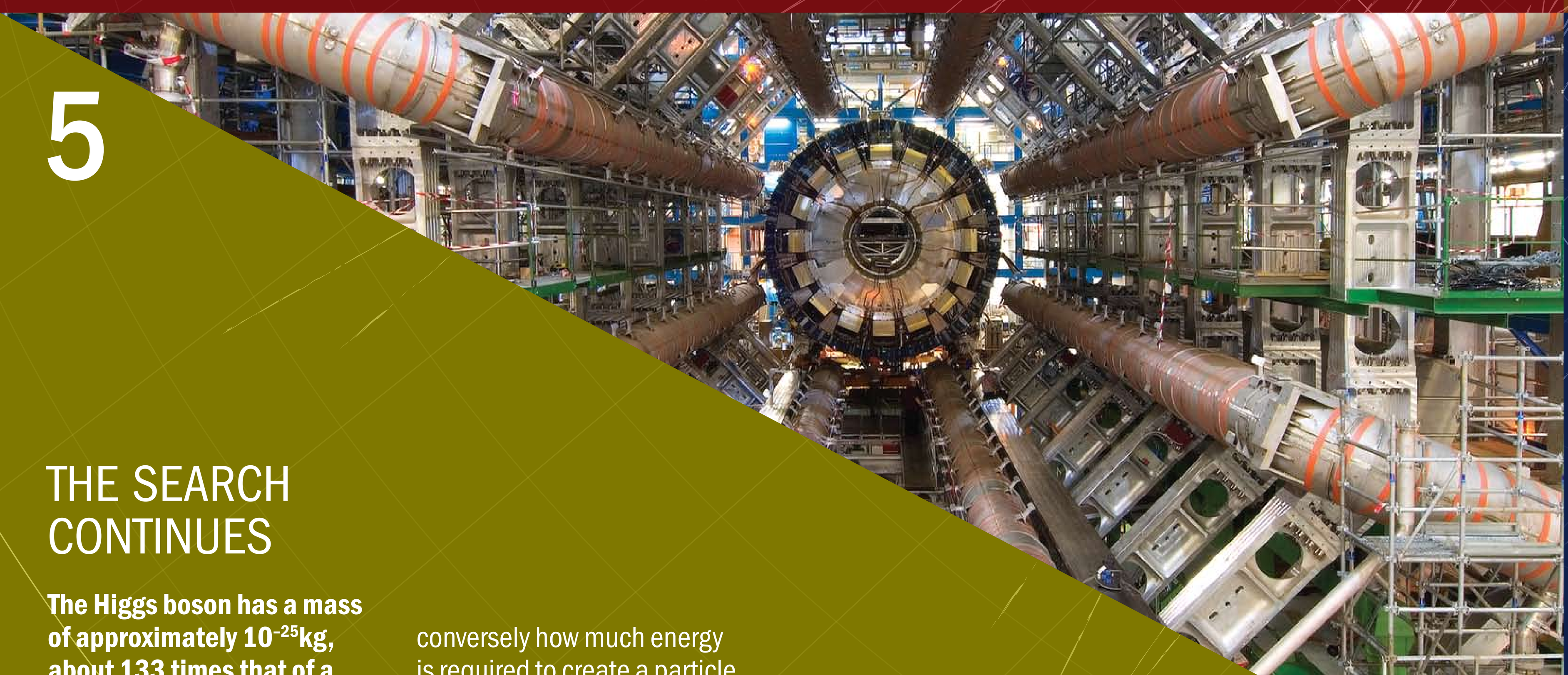

THE SEARCH CONTINUES

The Higgs boson has a mass of approximately 10^{-25}kg, about 133 times that of a proton. Albert Einstein's famous equation "$E=mc^2$" informs us that mass and energy are equivalent (E is energy, m is mass and c is the speed of light).

Using this equation it is possible to calculate the amount of energy that could be extracted from a particle of a certain mass, and conversely how much energy is required to create a particle of a certain mass. Since the mass of the Higgs boson is over a 100 times larger than that of a proton and only a small fraction of the proton's energy is used to create the Higgs boson, then proton beams of very high energy are required that are provided by the LHC, which accelerates each proton to 0.99999997 of the speed of light.

With the LHC up and running, the analysis of the data output is a formidable task. The Higgs boson can only be measured indirectly through measurement of the particles into which it decays, as it is not a stable particle – it has an expected existence time of less than a millionth of a billionth of a second! Ascertaining whether the Higgs boson exists is like trying to calculate the weight of a tiger by measuring the tracks it leaves in the mud.

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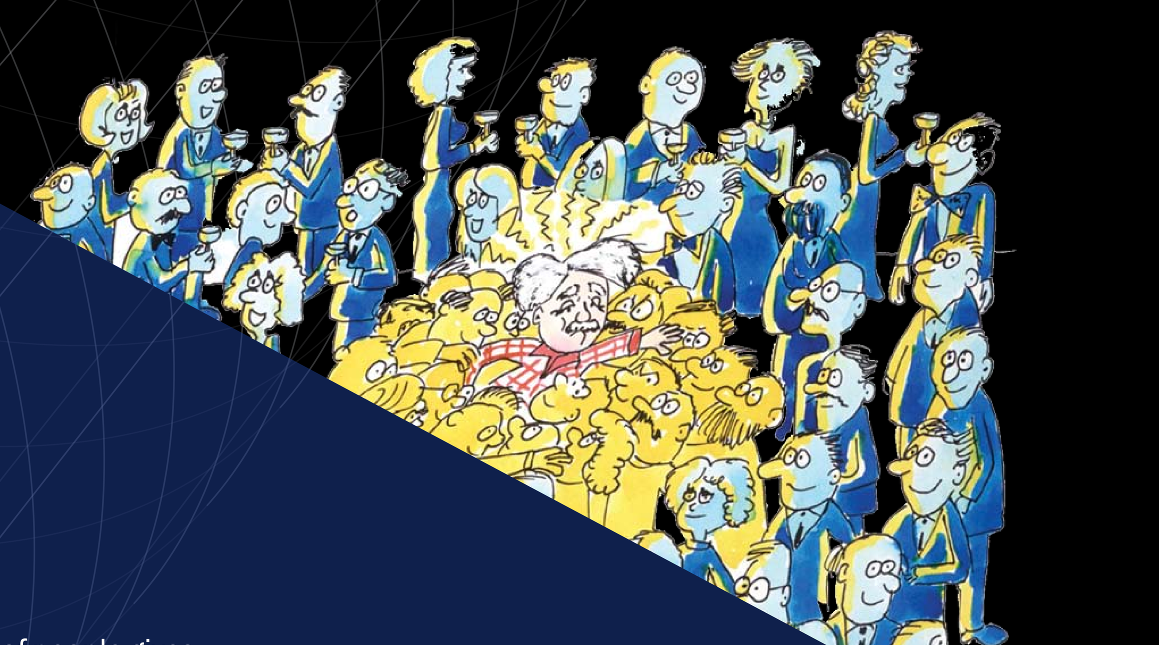

HOW DOES IT WORK?

A good analogy for how the Higgs boson gives the other particles mass is given by the so-called "political delegate" analogy, which we've modified to include one of the world's most revered physicists.

Imagine a room completely full of delegates, with a door at either end of the room. When Albert Einstein enters the room the delegates cluster around him, feverishly trying to get near enough to speak to him.

This crush of people gives inertia (mass) to the motion of Einstein across the room, making it very difficult for him to start moving and also very difficult for him to stop once going! By contrast, less famous scientists can move across the room without such a large crowd forming around them. These less famous scientists have much less inertia (mass) than Einstein.

In this analogy, the delegates are the Higgs field. The other fundamental particles are the various scientists entering the room. This analogy essentially describes how the Higgs mechanism gives things mass.

Remember, more scientific credibility and importance means more mass!

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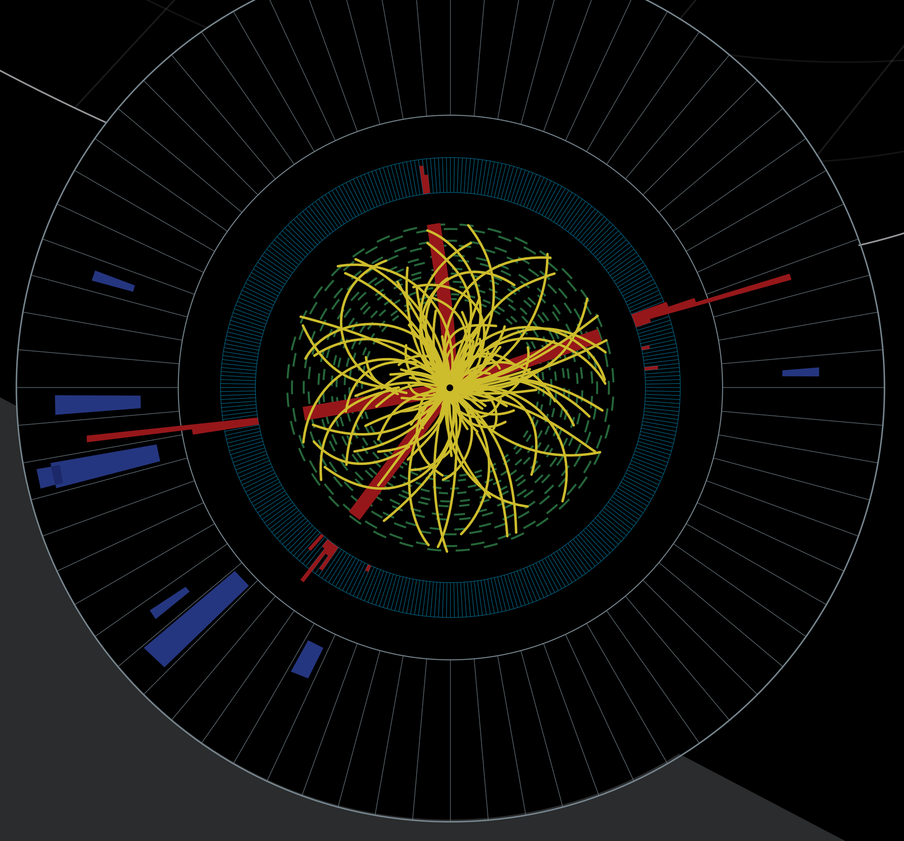

WHY IS IT SO IMPORTANT?

The property of mass is such an integral part of the universe, that without the existence of the Higgs field giving the fundamental particles various values of mass then the universe as we know it wouldn't exist!

If there were no Higgs mechanism, there would be no galaxies, no stars and no atoms. It is important to realise just how integral the Higgs boson is for the structure of everything familiar and unfamiliar in the universe around us.

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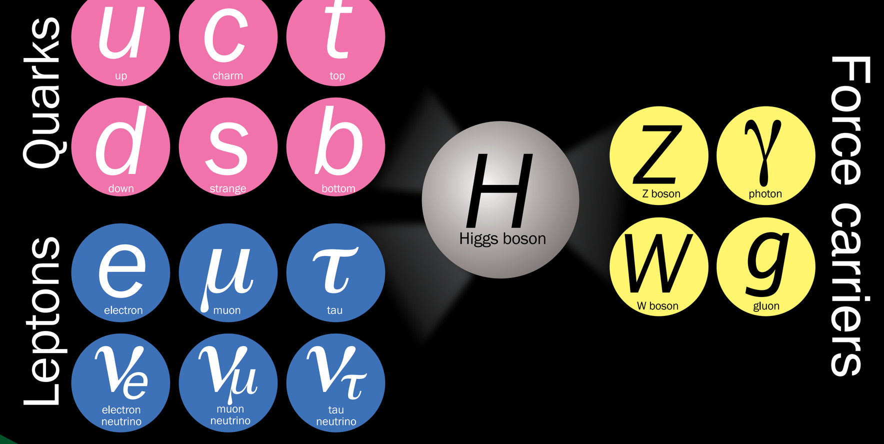

BEYOND DISCOVERY

The discovery of a Higgs-like particle certainly marks the beginning of a new epoch in the history of physics. We know more about the most fundamental level of matter and reality than ever before. The experimental discovery announced on 4 July 2012 demonstrates the predictive power of elegant mathematical theories to describe the universe.

The next stage of experimentation will be to work out exactly what kind of particle was discovered. There are different possible variants of the Higgs boson, corresponding to different conceptions of reality. It may turn out that the particle discovered corresponds to an exotic and unexpected Higgs boson.

The existence of such a particle may act as a gateway to a whole new level of physics and could point a way towards the solution of problems such as dark matter and quantum gravity. It is likely that the discovery of the Higgs boson is not one of the final pieces in the jigsaw of reality but an indication that we are standing on the edge of finding a new deeper level of reality than we have ever perceived before.

IOP Institute of Physics

Particle tracks from a proton–proton collision observed by the Compact Muon Solenoid detector at CERN. The Large Hadron Collider accelerates the protons that collide and create particles (the yellow lines), including the Higgs boson (which decays immediately, so is not visible). The Higgs boson decays into a pair of Z bosons that themselves decay into a pair of electrons and positrons (the long red lines).

For more information about this poster,
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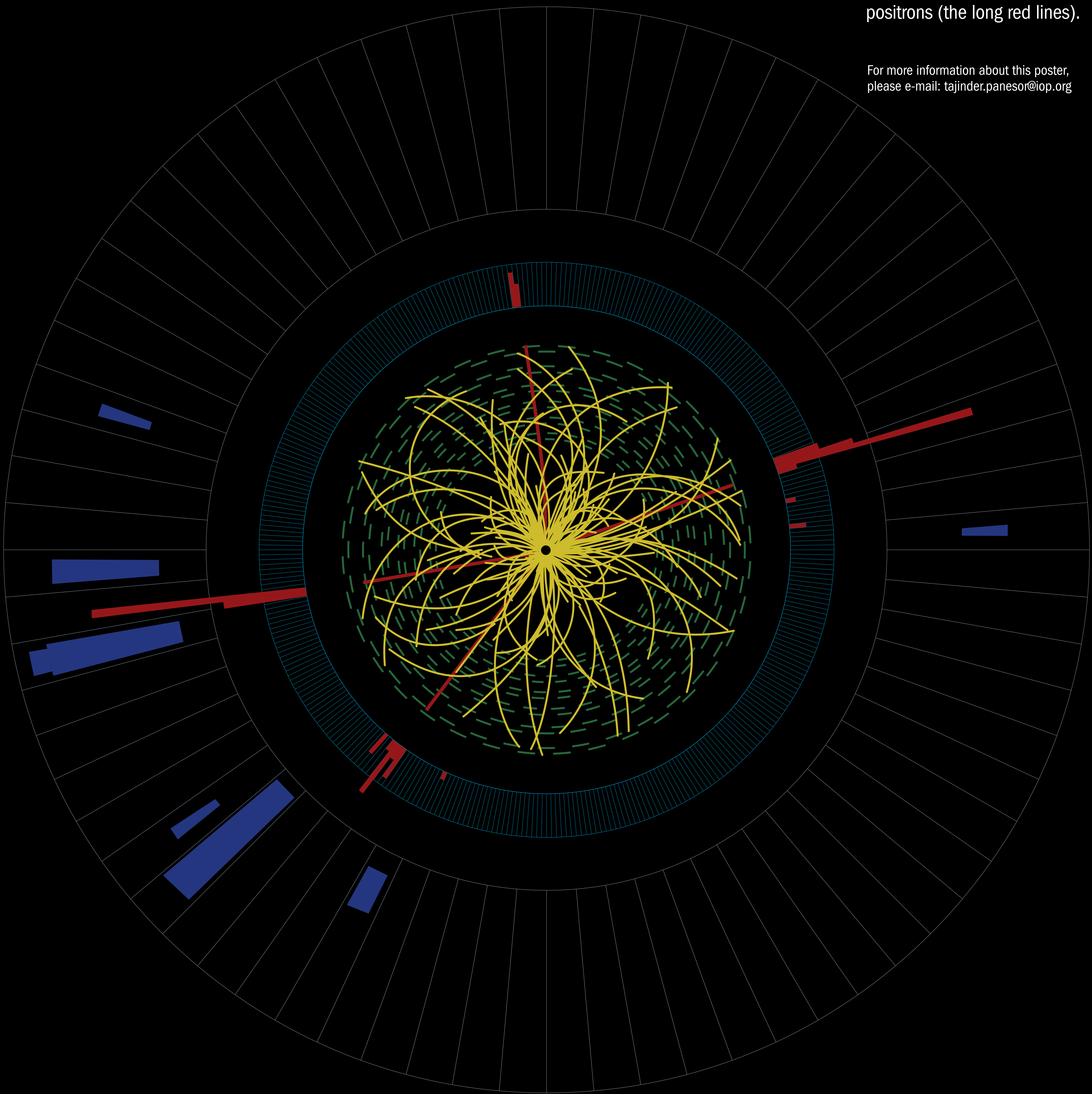

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HIGGS BOSON