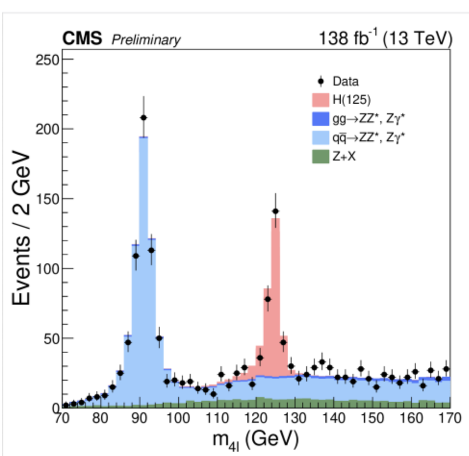
# The Sister Experiments

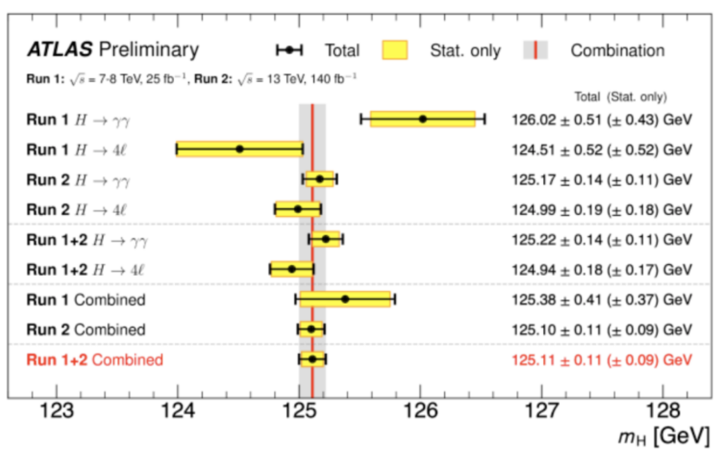
**Since the LHC start-up in 2009, the ATLAS and CMS general-purpose experiments have been pursuing two main goals: to draw a definitive conclusion about the existence (or not) of the Higgs boson, as predicted by the Standard Model; and to search far and wide for new physics effects.**

Thanks to the constant progress of the LHC collider, ATLAS and CMS have been accumulating data at an ever-increasing rate. Their operation began with the observation of well-known phenomena in order to calibrate the detectors. Thus, over the course of 2010, the two collaborations surveyed a century of accumulated knowledge, from the discovery of the electron in 1897 to that of the top quark in 1995.

Once the set was firmly established, ATLAS and CMS began addressing the core of their physics programme in 2011 and 2012. They aim to uncover unexpected phenomena beyond the Standard Model, such as new particles, while also conducting precision measurements that refine our understanding of the Standard Model and potentially reveal new physics if discrepancies with




Credit: CMS-CERN, ICHEP2024




Credit: ATLAS-CERN, 2023

***The Higgs boson mass according to ATLAS and CMS***

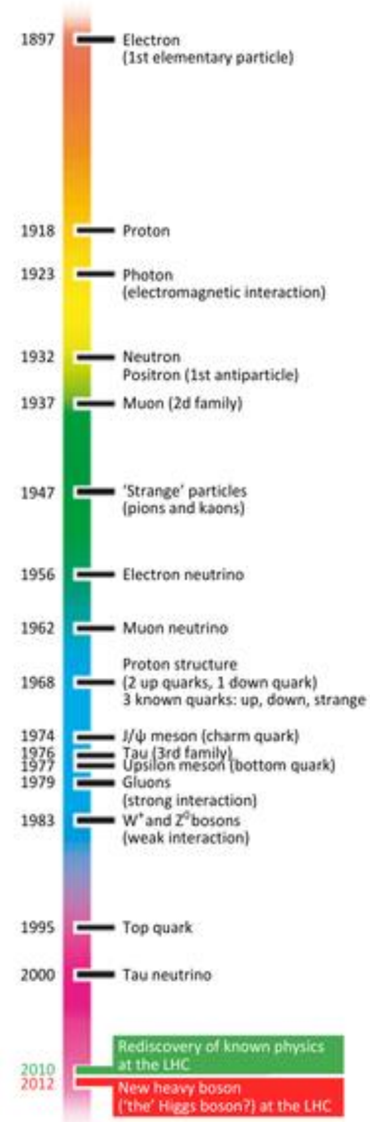
*On the left, mass measured by the CMS experiment for events selected as Higgs boson candidates. The signal is in red, whereas other known processes are in blue and green. The fitted curve allows to measure the Higgs boson mass with an uncertainty which decreases when the number of events and the understanding of the detector improve. On the right, one sees the results obtained by ATLAS on different Higgs boson decay channels, and the improvement over time. Both experiments have reached the per mil level at the end of the second LHC run, 10 years after the discovery.*

theoretical predictions arise. Since then, experimental results have continuously improved, driven by the growing volume of data available – which reduces statistical errors – and advancements in our understanding of the detectors – which minimise systematic uncertainties. Theoretical calculations benefit from these improved measurements and are also becoming increasingly precise. Finally, recently introduced machine learning techniques are powerful tools for distinguishing between signal and background noise. The performance has significantly surpassed the expectations of even the most optimistic experts.

For example, the mass of the top quark measured at the LHC is more precise than the measurement obtained by combining all previous results. Similarly, numerous measurements have been carried out on weak interaction mediator bosons ($W^+$, $W^-$, $Z^0$) and confirmed the validity of the Standard Model at unprecedented energies. These improvements naturally encourage theoretical physicists to fine-tune their calculations to improve the accuracy of their predictions, whether they are working within the Standard Model or one of its extensions.

On 4 July 2012, ATLAS and CMS announced the observation of a new particle, with a mass of around 125 GeV/$c^2$ (134 times the mass of the proton), and compatible with the famous Higgs boson. Over the years, their diagnostic has been refined thanks to advances in data analysis: this particle is ‘a’ Higgs boson. But is it ‘the’ Higgs boson whose existence was postulated nearly half a century ago to make the Standard Model coherent? Time will tell!

The physics programme of ATLAS and CMS experiments is not limited to the Higgs boson. Data is intensely scrutinised for any trace of a new particle or unexpected phenomena within the framework of the Standard Model. Despite all the efforts, this search has so far (July 2024) been fruitless: no signs of a supersymmetric particle, a mini black hole, an extra dimension, a ‘hybrid’ particle halfway between a quark and a lepton, a new quark, or a Higg boson other than the one already observed. But not all the new physics ‘signatures’ have yet been explored, and experiments currently have access to only a tenth of the data that the accelerator will have delivered by 2042.




*Credit: CERN*

***Particle discoveries timeline***

*This timeline shows the dates when new particles were discovered. The particles known at the dawn of the 21st century were all ‘rediscovered’ within a few months by the LHC experiments. In July 2012, ATLAS and CMS announced the discovery of a new boson, later identified as a Higgs boson, the detailed study of which remains a key priority for the coming decades.*

***Translated from ‘Les résultats d’ATLAS et de CMS’,* Passeport pour les deux infinis*, IN2P3/Dunod, https://pass2i.ijclab.in2p3.fr/ (French); updated with ICHEP2024 conference (https://ichep2024.org) for IPPOG***