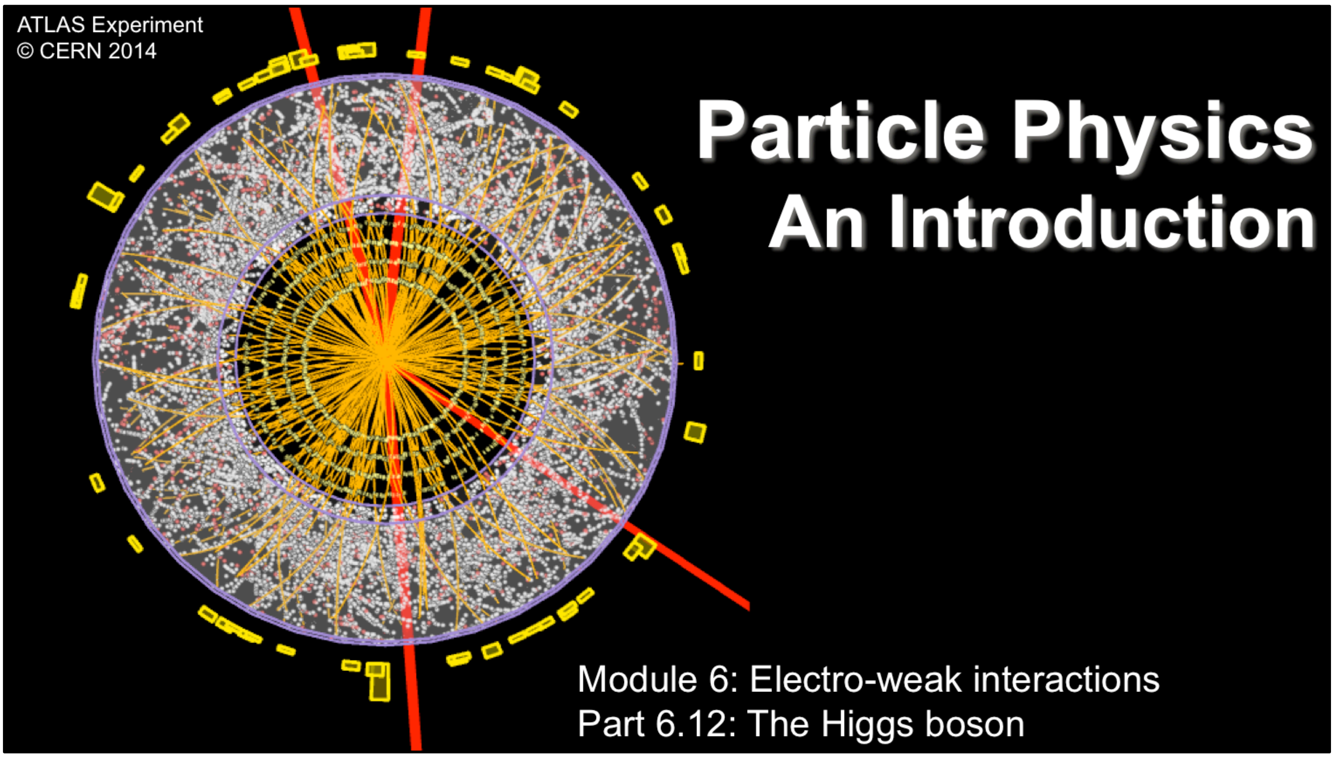
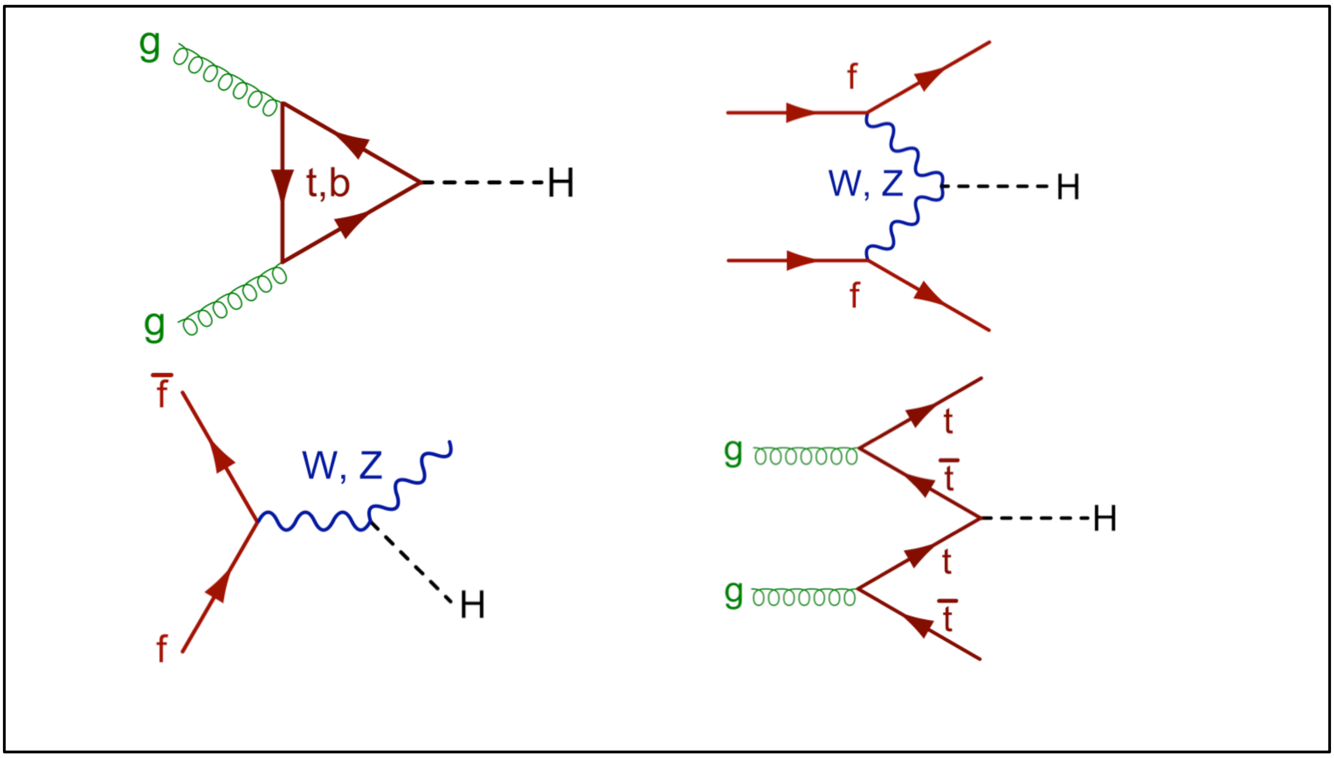



In this sixth module, we discuss electro-weak interactions and the Higgs mechanism.

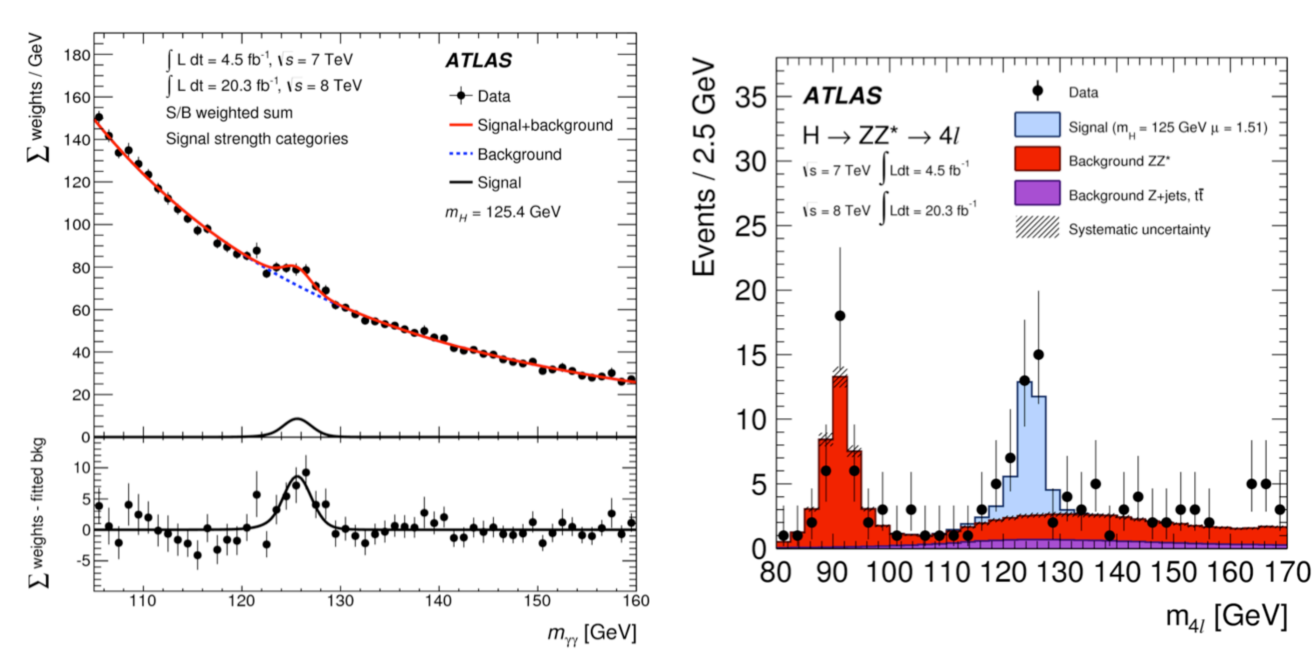
In this 12$^{th}$ video we will encounter the particle associated with the Higgs field, the Higgs boson.

After following this video you will know:

- How the Higgs boson is produced at the LHC;
- How we identify its production and decay;
- How it is verified, that it has the properties required for a Higgs boson.

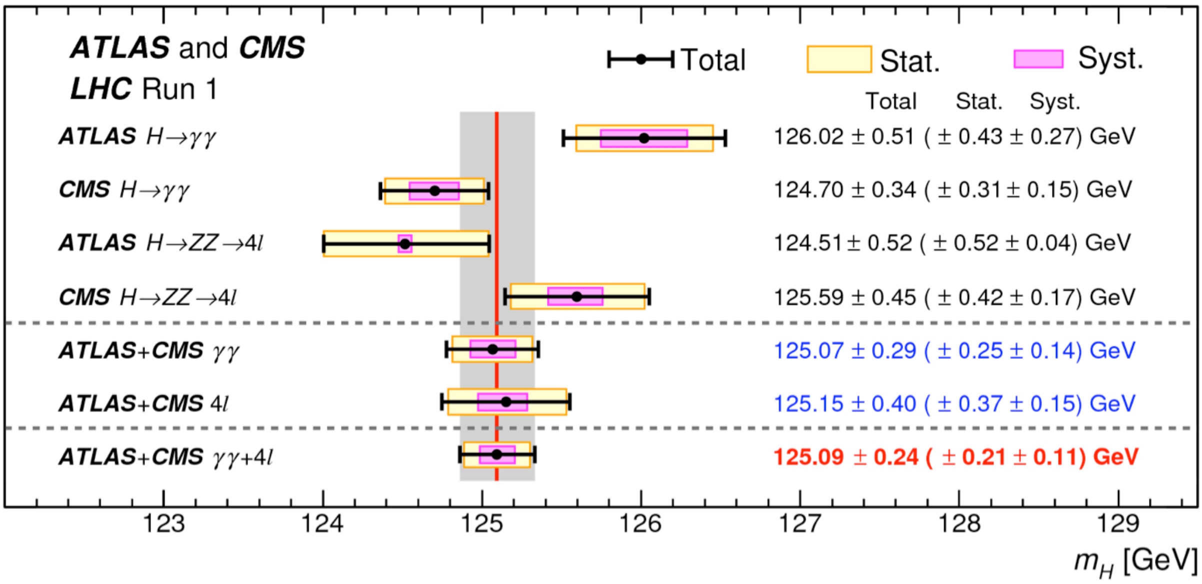



- The **Higgs field** is a microscopic field that must be quantized. There is a particle, which corresponds to the $\Phi$ field, the **scalar Higgs boson $H^0$**.
- All its **properties** were known before it was discovered, except its existence and its mass. In particular, its branching ratios into different fermion-antifermion or boson-boson pairs are fixed once the mass is known.
- The Higgs boson can be produced as a real particle at a **hadron collider**, provided its energy is sufficient. This is the case for the LHC. Here we show some Feynman diagrams for the production of a Higgs boson from two protons, either by quarks or by gluons.
- The existence of the Higgs boson $H^0$ has been confirmed in a spectacular way by the experiments **ATLAS and CMS at the LHC** in 2012.



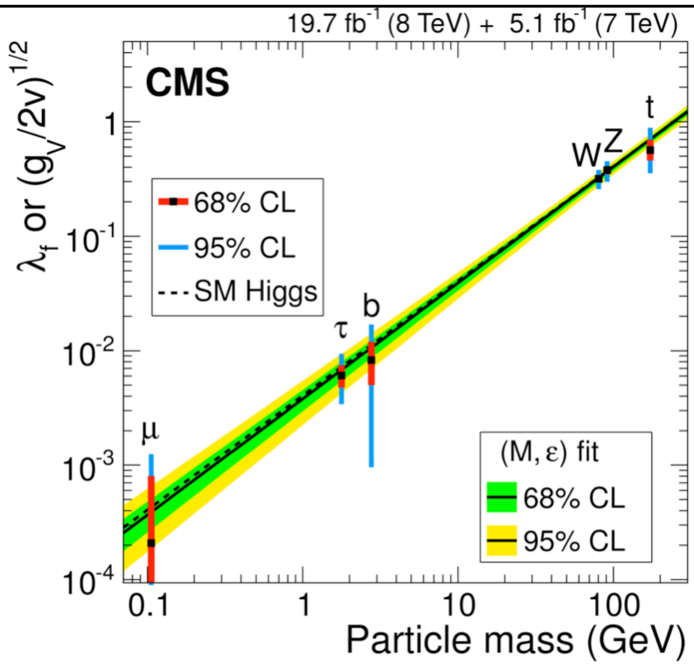

ATLAS Collab., G. Aad et al., Phys. Rev. D. 90 (2014) 112015, Phys. Rev. D 91 (2015) 012006

- Higgs boson production is detected, among other methods, in the invariant mass distribution of **photon pairs or pairs of Z bosons**. The latter ones decay in turn into lepton-antilepton pairs. A four-lepton event from the ATLAS experiment with four muons in the final state, serves as the logo of this course.
- The signal at a mass of about **125 GeV** sticks out clearly above the background of other production mechanisms, which do not involve Higgs bosons.
- Indeed we have here a second nice example of particle mass measurement through the **invariant mass of its decay products**.




ATLAS and CMS Coll., G. Aad et al., Phys.Rev.Lett. 114 (2015) 191803

- The **measurements** from the two experiments at the LHC give compatible results, which can be combined. This determines today the mass of the Higgs boson $H^0$ to be 125 GeV with a precision of about 240 MeV, i.e. about 2 parts per thousand. This is a remarkable achievement by these experiments and is the fruit of the work of thousands of physicists and engineers during two decades.




CMS Coll., V. Khachatryan et al, Eur. Phys. J. C 75 (2015) 212

The experimental findings today can be summarized as follows:

- The $H^0$ is a **well established new particle**, the probability that background fluctuates upwards to simulate the signal is of the order of 1 to several hundred million.
- It is indeed a **boson**, because its decay into two photons is observed. It very probably has **spin 0.**
- Its **couplings** to different particles are indeed proportional to their apparent masses, as they should. Here we show a summary of results from the CMS experiment.
- We are thus sure that $H^0$ is indeed a **Higgs boson**. This, however, does not exclude the existence of other bosons of this type, which are obviously actively hunted by experiments at the LHC.
- In the next Module, Anna will go into more details about how to **search for new phenomena** in the challenging environment of a hadron collider.

MINUTE PHYSICS

The Higgs Boson, Part I : http://www.youtube.com/watch?v=9Uh5mTxRQcg
The Higgs Boson, Part II : http://www.youtube.com/watch?v=ASRpIym_jFM
The Higgs Boson, Part III : http://www.youtube.com/watch?v=6guXMfg88Z8

- If you want to know more about the Higgs mechanism and its working principles, I recommend these three episodes of the excellent series **"Minute Physics"** from the Perimeter Institute in Waterloo, Canada. You will easily find them on YouTube.

To conclude our discussion of the Higgs boson, the next video contains an interview with one of the key people, who contributed to its discovery.