EIROforum

Serving European Science

The European Organisation for Nuclear Research (CERN)

use of particle accelerators and detectors to study the basic constituents of matter

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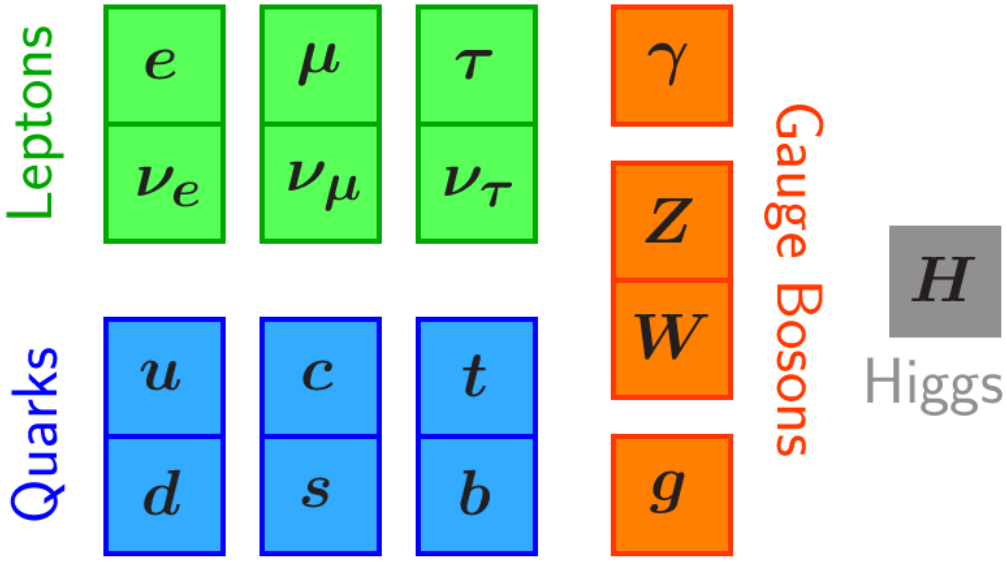
Particle physics and the Higgs boson

Standard Model of Particle Physics describes all known elementary particles and their interactions (i.e. roughly 5% of the matter/energy density of the universe)

- Matter: 6 quarks and 6 leptons
- Forces mediated by gauge bosons
- Experimentally tested and refined over the last 30 years



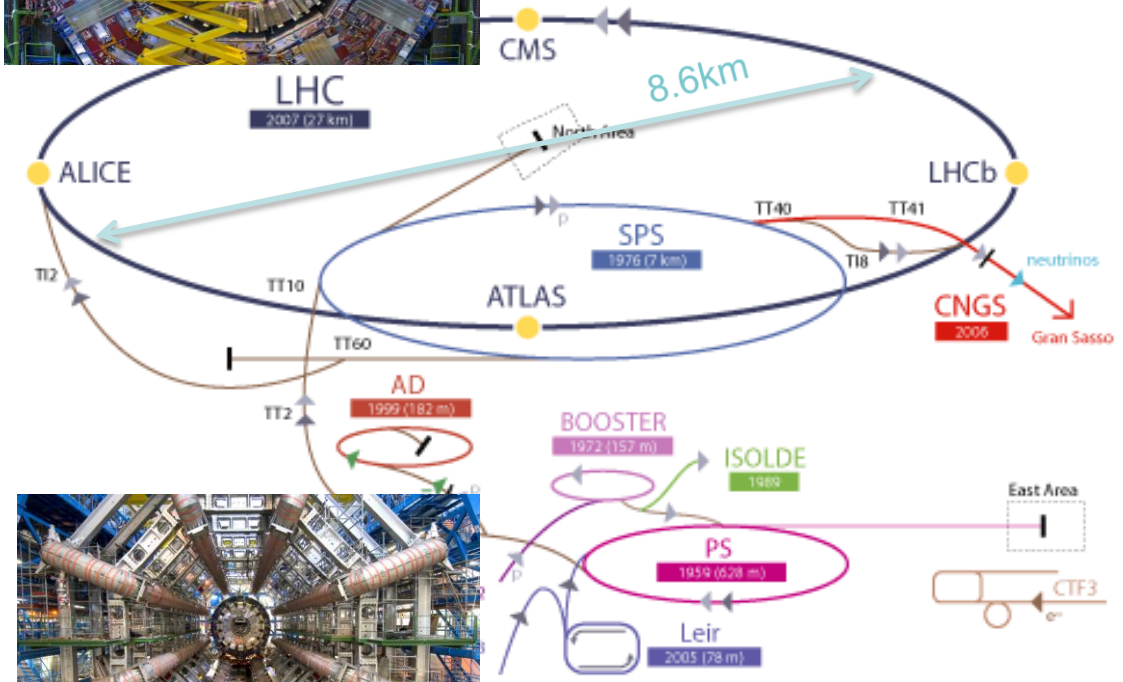
Missing link (so far?): Higgs boson

- Responsible for giving mass to massive particles
- Required for internal consistency of the Standard Model
- Predicted in 1964 and searched for in many experiments

Search for the Higgs boson was one primary motivation for building the Large Hadron Collider at CERN

The Large Hadron Collider (LHC)

CMS



ATLAS

Large Hadron Collider (LHC):

Proton-proton collisions (7-8 TeV)

- Highest achieved energy in particle colliders
- Operational since 2009
- 13-14 TeV from 2015 onwards

ATLAS and CMS Experiments

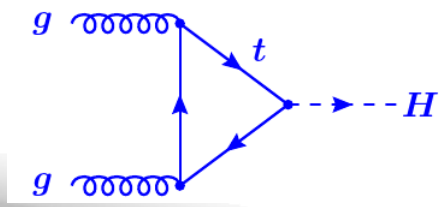
- Search for the Higgs boson
- Search for dark matter, new particles, extra dimensions, …
- International collaborations (>3000 members (from ~40 countries) per experiment)

Other Experiments at LHC: Alice, LHCb, TOTEM, LHCf, MoEDAL

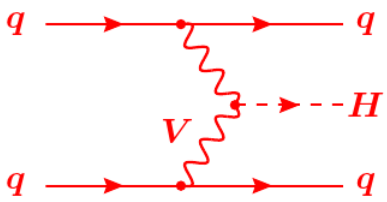
Higgs boson production and decays

Standard Model makes precise predictions how Higgs bosons are produced and decay

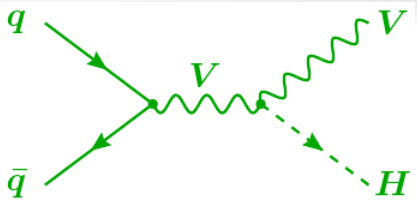
Production
In collisions of protons



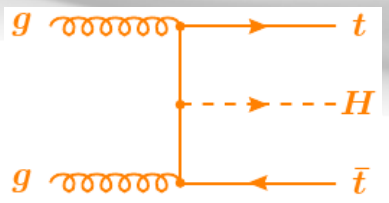
Fusion of 2 gluons



Fusion of 2 gauge bosons (W or Z)



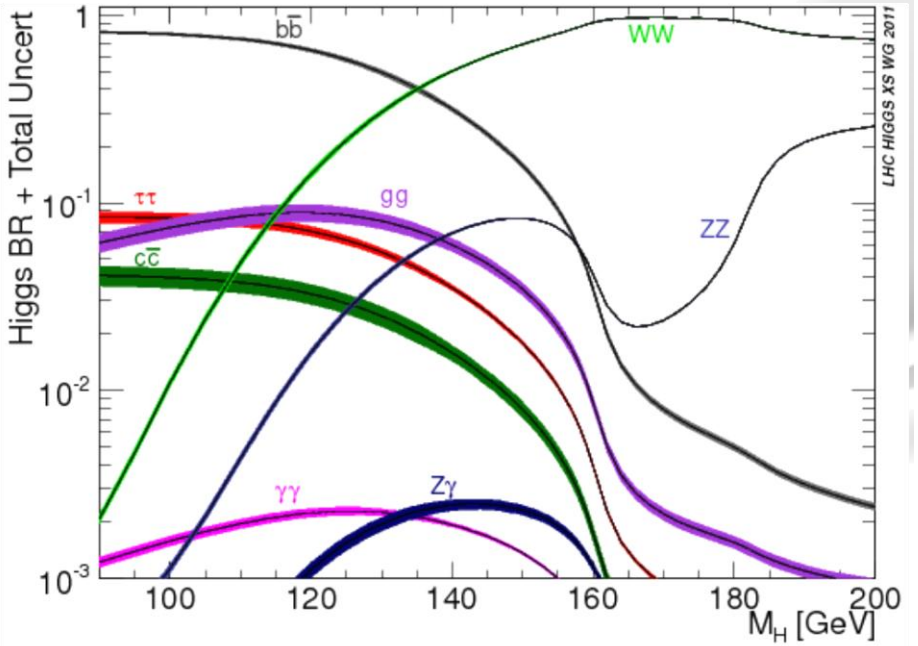
Together with a gauge boson (W or Z)



Together with top quarks

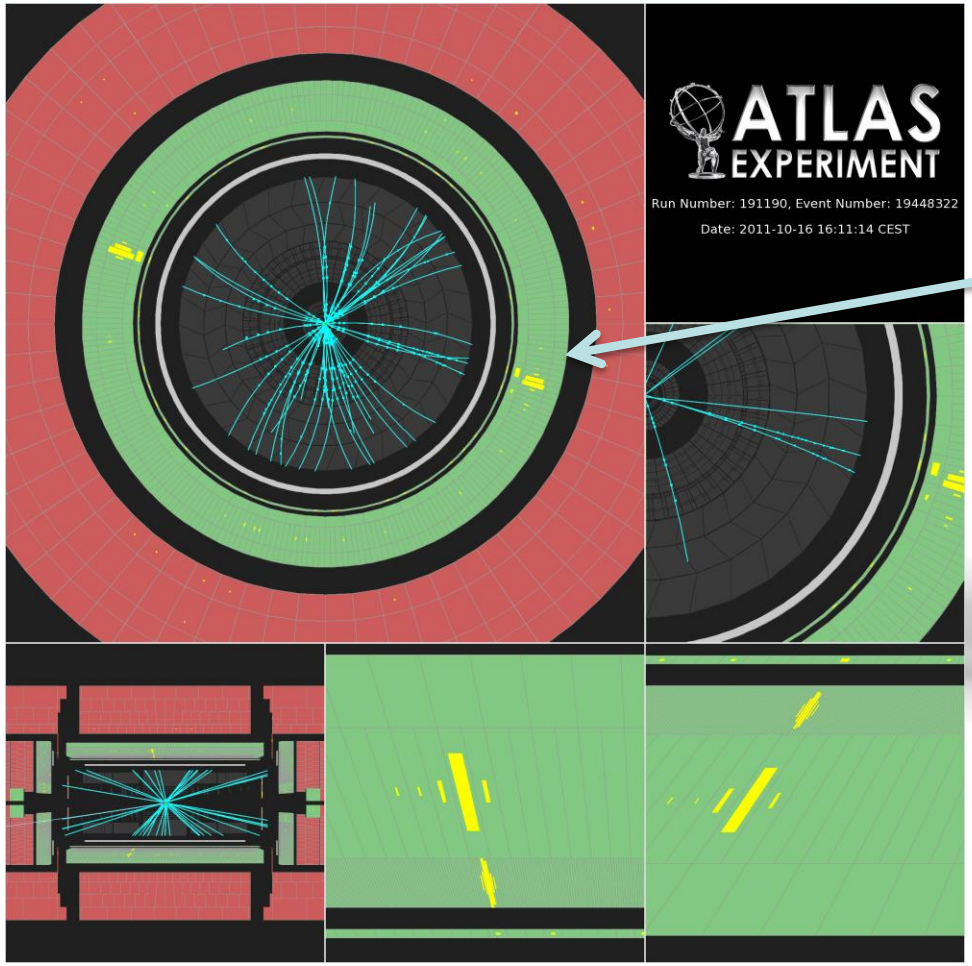
Decay probabilities depend on its mass

Higgs boson mass is not predicted!



→ Look in all possible final states
(Higgs boson decays immediately)

Example: Searching for Higgs boson decays into two photons

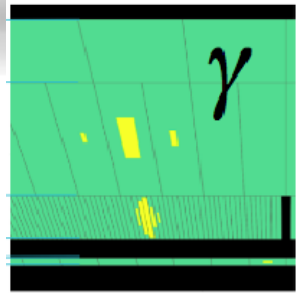


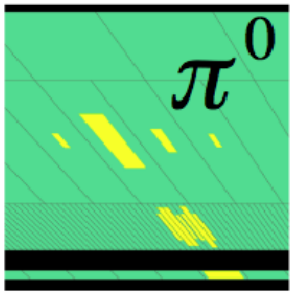
Decay into two photons has small probability, but simple final state to reconstruct

- 2 highly energetic isolated photons

Challenge: distinguish photons from much more numerous hadronic jets.

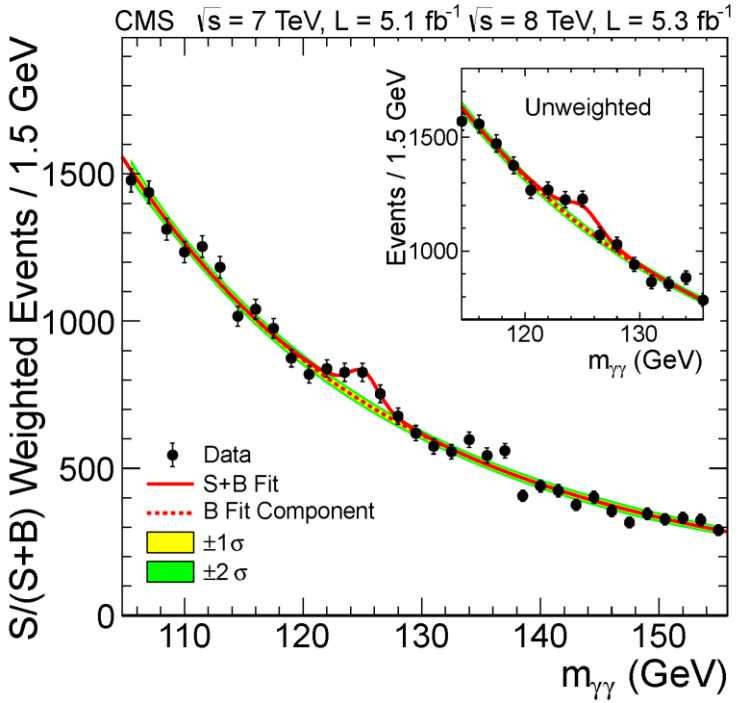
Both ATLAS and CMS have sophisticated electromagnetic calorimeters to measure energy and identify photons



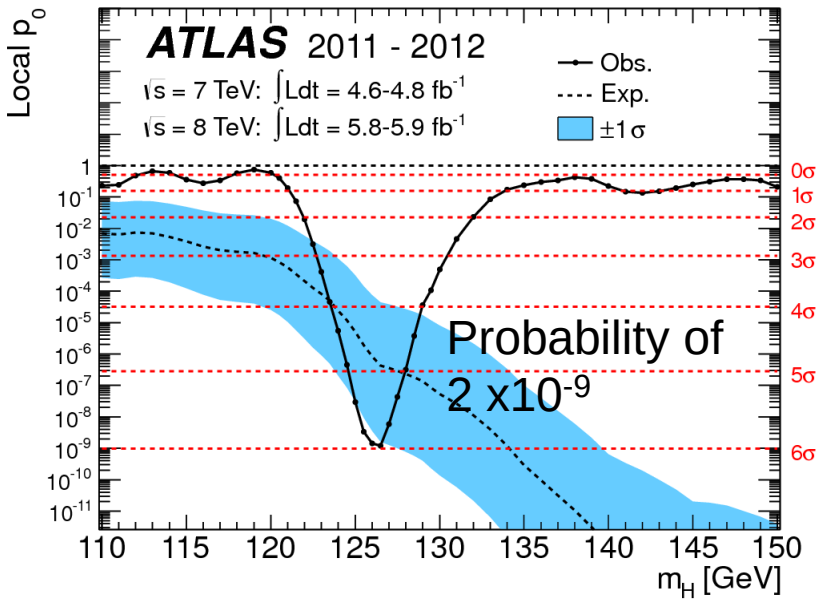


Discovery of a new particle

Clear signal in events with 2 photons:



Combining results of searches in several different final states: Can they be explained without a new particle?



New particle discovered by the ATLAS and CMS experiments with mass ~125GeV

Is the new particle the (Standard Model) Higgs boson?

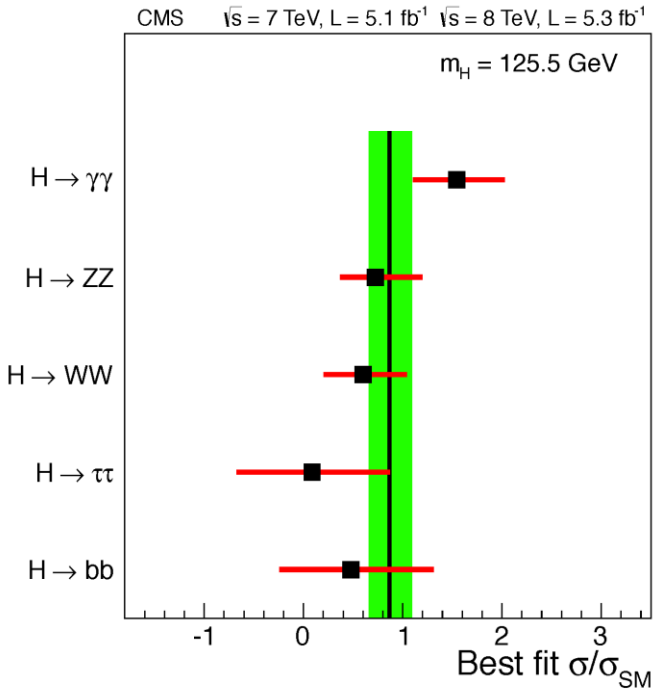
We already know the new particle is fundamentally different from the so-far known particles

Need to measure the properties of the new particle

- How often does it decay into which final state?
- Is it produced as we expect from a Higgs boson?

→ How does it "couple" to the other particles

- What is its spin (intrinsic angular momentum)?
- How does it behave under CP transformations?
  - ❖ Spatial and particle/antiparticle symmetry

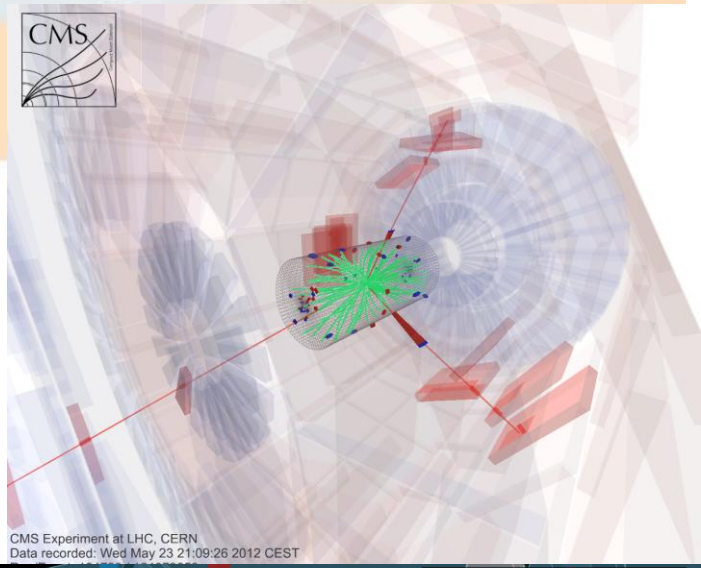


So far, properties are consistent with those expected from a SM Higgs boson

But this is just the beginning of a long program of detailed measurements

Summary

- ATLAS and CMS experiments have found a new particle with mass ~125 GeV
- Start of a long program of detailed measurements of its properties: Is it the Standard Model Higgs boson, or a Higgs boson from an extended model, or something completely different?



- Looking forward to study the nature of the new particle
  - Are we learning where the mass of elementary particles is coming from?
  - Will it give us hints for solutions for other open questions in particle physics: dark matter, …?