# ATLAS Experiment searches for rare Higgs boson decays into muon pairs

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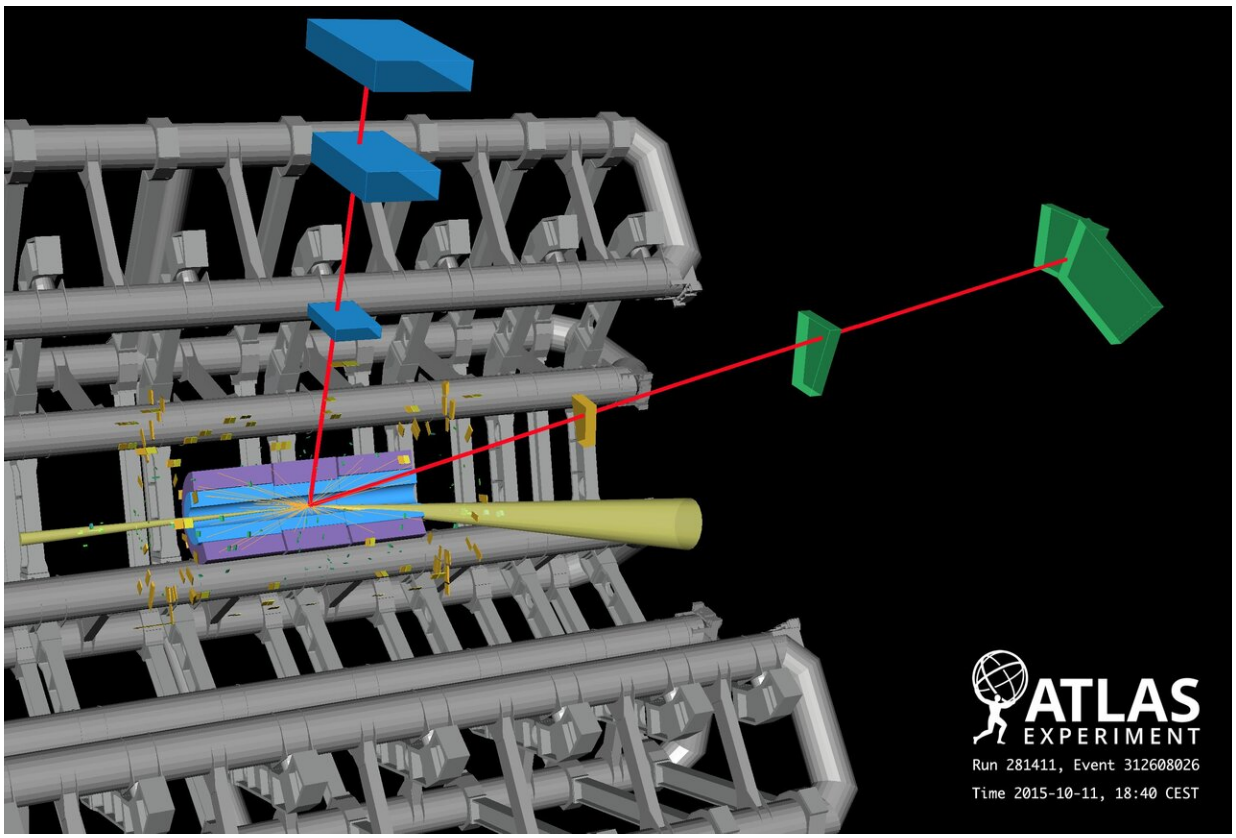


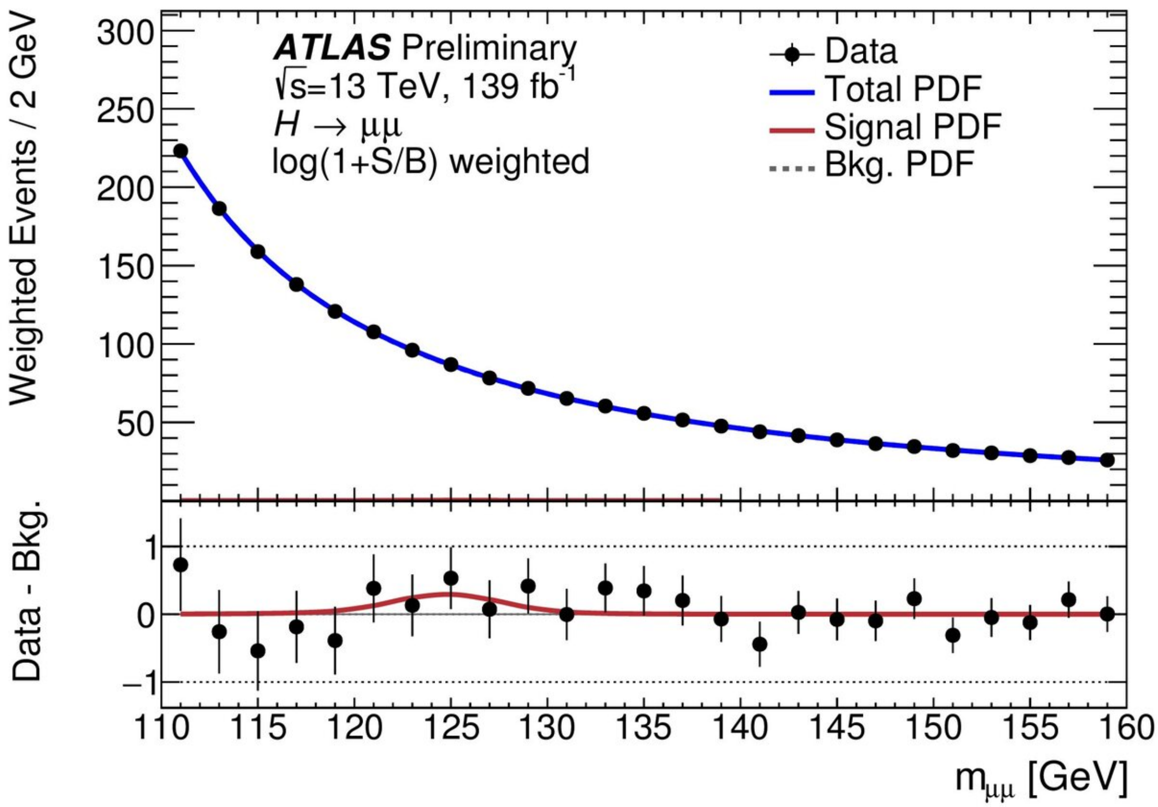

A Higgs boson candidate event decaying to two muons (red) and two jets (yellow cones) in the ATLAS detector. Credit: ATLAS Collaboration/CERN

Could the Higgs boson still surprise us? Since its discovery in 2012, the ATLAS and CMS collaborations at CERN have been actively studying the properties of this latest and most mysterious addition to the Standard Model of particle physics.

In the Standard Model, the Brout-Englert-Higgs mechanism predicts the Higgs boson will interact with matter particles (quarks and leptons, known as fermions) with a strength proportional to the particle's mass. It also predicts the Higgs boson will interact with the force carrier particles (W and Z bosons) with a strength proportional to the square of the particle's mass. Therefore, by measuring the Higgs boson decay and production rates, which depend on the interaction strength to these other particles, ATLAS physicists can perform a fundamental test of the Standard Model.

Last week, at the European Physical Society Conference on High-Energy Physics (EPS-HEP) in Ghent, Belgium, the ATLAS Collaboration released a new preliminary result searching for Higgs boson decays to a muon and antimuon pair ($H \rightarrow \mu\mu$). The new, more sensitive result uses the full Run 2 dataset, analysing almost twice as many Higgs boson events as the previous ATLAS result (released in 2018, for the ICHEP conference).

Both the ATLAS and CMS Collaborations have already observed the Higgs boson decaying to tau lepton – the muon's heavier cousin, belonging to the third "generation" of fermions. Since muons are much lighter than tau leptons, the Higgs boson decay to a muon pair is expected to occur about 300 times less often than that to a tau-lepton pair. Despite this scarceness, the $H \rightarrow \mu\mu$ decay offers the best opportunity to measure the Higgs interaction with second-generation fermions at the LHC, providing new insights into the origin of mass for different fermion generations.




This new ATLAS result shows a search for the Higgs boson decaying to a pair of muons. The measured muon pair mass distribution is shown, combined over all categories. Credit: ATLAS Collaboration/CERN

Experimentally, ATLAS is well-equipped to identify and reconstruct muon pairs. By combining measurements from the ATLAS inner detector and muon spectrometer, physicists can achieve a good muon momentum resolution. However, they must also account for muons being created by a common background: the abundant "Drell-Yan process", where a muon pair is produced via the exchange of a virtual Z boson or a photon. To help differentiate the $H \rightarrow \mu\mu$ signal from this background, ATLAS teams use multivariate discriminants (boosted decision trees), which exploit the different production and decay properties of each event. For example, H → μμ signal events are characterised by a more central muon pair system and a larger momentum in the plane transverse to the colliding protons.

To further enhance the sensitivity of the search, physicists separate the potential H → μμ events into multiple categories, each with different expected signal-to-background ratios. They examine each category separately, studying the distribution of the mass of the muon pair of the selected events. The signal and background abundances could then be determined simultaneously by a fit to the mass spectrum, exploiting the different shapes of the signal and background processes. Figure 2 shows the resulting muon pair mass distribution combined over all the categories.

In the new ATLAS result, no significant excess of events above the measured background was observed in the signal region around the Higgs boson mass of 125 GeV. The observed signal significance is 0.8 standard deviations for 1.5 standard deviations expected from the Standard Model. An upper limit on the Higgs boson production cross section times branching fraction to muons was set at 1.7 times the Standard Model prediction at 95% confidence level. This new result represents an improvement of about 50% with respect to previous ATLAS results.

**More information:** A search for the dimuon decay of the Standard Model Higgs boson in proton-proton collisions at 13 TeV with the ATLAS Detector (ATLAS-CONF-2019-028) : atlas.web.cern.ch/Atlas/GROUPS … ATLAS-CONF-2019-028/

Provided by ATLAS Experiment