New milestone reached in the study of electroweak symmetry breaking

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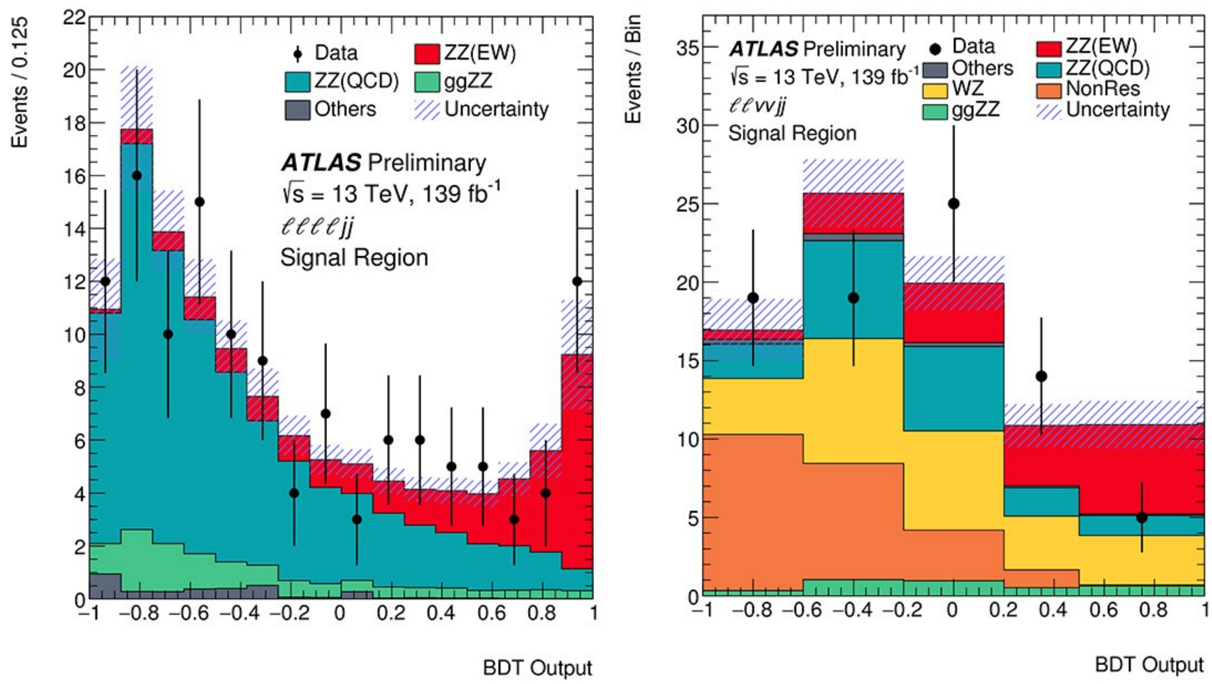

Observed and predicted BDT distributions in the signal regions (left for the four-lepton channel and right for the two-lepton and two-neutrino channel). Credit: ATLAS Collaboration/CERN

In the Standard Model of particle physics, elementary particles acquire their masses by interacting with the Higgs field. This process is governed by a delicate mechanism: electroweak symmetry breaking (EWSB). Although EWSB was first proposed in 1964, it remains among the least understood phenomena of the Standard Model as a large dataset of high-energy particle collisions is required to probe it.

After the discovery of the Higgs boson in 2012, the investigation of EWSB at the high-energy frontier began in earnest at the Large Hadron Collider (LHC) at CERN. Aside from precisely measuring the properties of the Higgs boson—in particular, its self-coupling—a key avenue to probing EWSB is the study of the high-energy behaviour of W and Z bosons as they scatter off one another. This process, which is governed by electroweak interactions, is known as massive vector boson scattering.

Vector boson scattering is one of several electroweak processes that contribute to the production of a pair of W or Z bosons in association with two "jets" of hadronic particles (each originating from a quark), which are produced preferentially opposite to each other in direction along the proton beams. Without the Higgs boson, the rate of this process would grow indefinitely with the collision energy. The EWSB mechanism should precisely cancel out this uncontrolled growth, according to the Standard Model. However, potential new physics processes could influence the rate of this process at high energy, making its precise measurement an important objective for the LHC experiments.

ATLAS physicists search LHC collisions for the electroweak production of two jets in association with a pair of massive vector bosons—either $W^{\pm}W^{\pm}$, $W^{\pm}Z$ or ZZ. These analyses are very challenging due to the scarceness of the signal in presence of a large, irreducible strong-interaction background. To improve the signal detection sensitivity, ATLAS physicists searched for events where the vector bosons had decayed to leptons, and they applied multivariate techniques to exploit subtle differences between signal and background events.

ATLAS successfully observed electroweak production of two jets in association with $W^{\pm}W^{\pm}$ and $W^{\pm}Z$ in 2018, using 36 fb^{-1} of 13 TeV proton–proton collision data. These results were achieved thanks to the large amount of data provided by the LHC, a carefully optimised search methodology, and the excellent calibration of the ATLAS detector to guarantee a precise measurement of leptons and jets. No significant deviation from Standard Model predictions was seen in these measurements.

Physicists then set out to observe the electroweak production of two jets in association with ZZ—the rarest of the three processes. The CMS collaboration searched for this process using 36 fb^{-1} of data, but found no clear evidence yet.

At the European Physical Society Conference on High-Energy Physics (EPS-HEP) in Ghent, Belgium, ATLAS presented a new search for this process using the full Run 2 dataset (139 fb^{-1}). The result combines two different channels originating from the decays of the Z-boson pair: four charged-leptons and two charged-leptons plus two neutrinos, respectively. Multivariate discriminants in form of Boosted Decision Trees (BDT) are trained to enhance the separation between the signal and background. The observed BDT distributions in both channels are examined together with a statistical method to determine the signal abundance.

The new ATLAS result provides the observation of the electroweak production of two jets in association with ZZ, with a statistical significance of 5.5 standard deviations. It is compatible with the Standard Model expectation of 4.3 standard deviations.

The observation of this process marks another milestone in the study of EWSB. Further scrutiny of EWSB will continue in other channels as well as with future datasets at the LHC.

More information: Observation of electroweak production of two jets in association with a Z-boson pair in proton-proton collisions at 13 TeV with the ATLAS detector (ATLAS-CONF-2019-033): atlas.web.cern.ch/Atlas/GROUPS … ATLAS-CONF-2019-033/

Provided by ATLAS Experiment