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The case of Higgs boson production in $H \to ZZ^*$ decay

Introduction to the Particle Physics Data Analysis

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Outline

Physics motivation

The physics motivation for the measurement:

- a good test for the SM,
- a measurement of inclusive and differential fiducial cross sections,
- tests of the spin and parity of the Higgs boson,
- test of perturbative QCD calculations.

The Feynman diagram

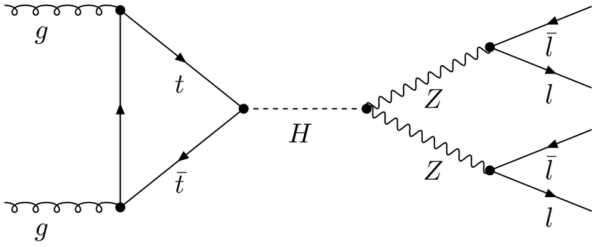

Figure: Feynman diagram for $H \to ZZ^* \to 4\ell$ decay [3].

Event selection

The final event-selection criteria for ZZ^* production:

- single-electron or single-muon trigger satisfied,
- exactly four leptons (electrons or muons) with $p_T > 25, 15, 10, 7 GeV$, respectively,
- Higgs-boson candidates are formed by selecting two *SFOS* lepton pairs,
- the leading pair is defined as the *SFOS* [1] pair with the mass $m_{\ell\ell,1}$ closest to the Z boson mass m_Z, and the subleading pair is defined as the SFOS pair with the mass $m_{\ell\ell,1}$ second closest to m_Z. [1]

[1] *SFOS* - Same Flavour, Opposite Charge

Cutflow Histogram

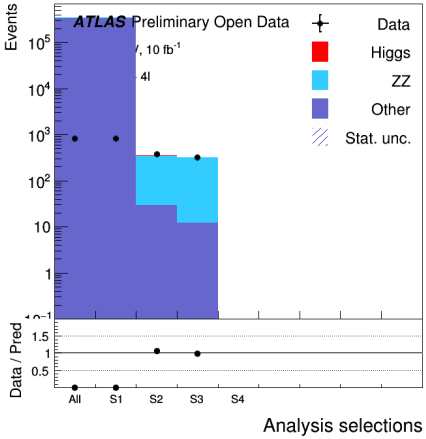

Figure: The cutflow histogram: $S1$ - single-electron or single-muon trigger satisfied, $S2$ - four leptons with $p_T > 25, 15, 10, 7 GeV$, $S3$ - two SFOS lepton pairs.

Expected number of events

Expected number of events equals:

$$N^{H\to ZZ^*\to 4\ell} = \sigma_{incl}^{H\to ZZ^*\to 4\ell} \cdot L_{int}, \tag{1}$$

where:

$$\sigma_{incl}^{H\to ZZ^*\to 4\ell} = 3{,}62\ fb^{-1},$$
$$L_{int} = 10{,}06\ fb^{-1}.$$

$$N^{H\to ZZ^*\to 4\ell} = 3,62\ \mathrm{fb} \cdot 10,06\ \mathrm{fb}^{-1} = 36,42. \tag{2}$$

Background contributions

Processes constituting background of our analysis:

- non-resonant SM ZZ* production,
- $t\bar{t}$ production,
- Z+jets production.

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Number of Leptons

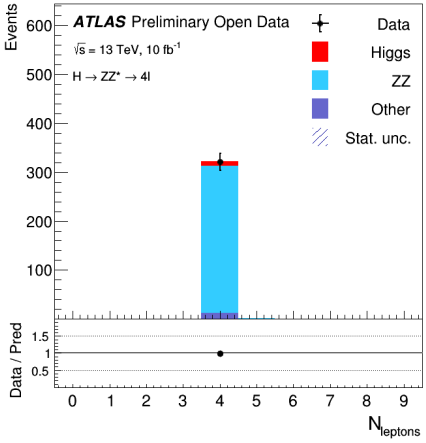

Figure: The histogram with number of leptons.

Cross-section measurement

Cross-section of $H \to ZZ^* \to 4\ell$ was calculated using the following formula:

$$\sigma^{H\to ZZ^*\to 4\ell} = \frac{N_{data} - N_{bkg}}{C \cdot L_{int}} = \frac{N_{obs}}{C \cdot L_{int}}, \tag{3}$$

where:

N_{data} - number of all events in data; $N_{data} = 321$,
N_{bkg} - nubmer of background events; $N_{bkg} = 315$,
N_{obs} - number of observed $H \to ZZ^* \to 4\ell$; $N_{obs} = 6$,
C - correction factor; $C = 0.525$,
L_{int} - integrated luminosity; $L_{int} = 10.06\,\mathrm{fb}^{-1}$.

$$\sigma^{H\to ZZ^*\to 4\ell} = \frac{321 - 315}{0.525 \cdot 10.06} = \frac{6}{0.525 \cdot 10.06} = 1,136\,[\mathrm{fb}] \tag{4}$$

Systematic uncertainties

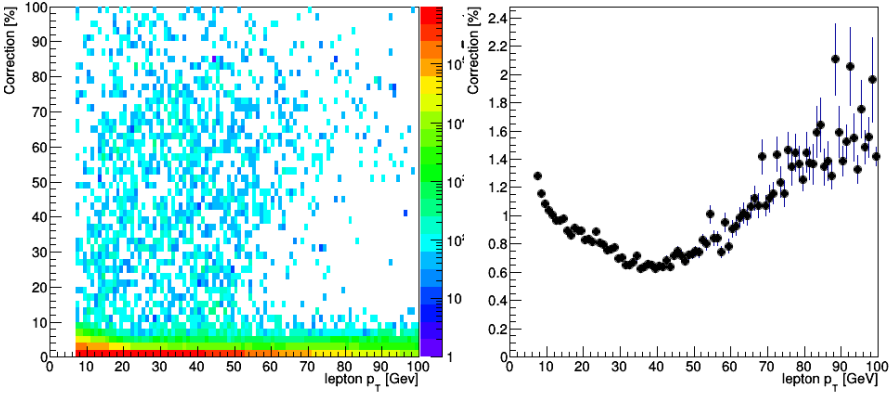

Figure: The histogram shows a size of correction in percentages for the MC data in the analysis. The correction is below 2.5%.

Systematic uncertainties

The cross-section measurement was repeated with correction on leptons' traverse momentums.

Case 1: The systematic uncertainties were added to the leptons' traverse momentums. **Four** events were observed.

$$\delta_{syst,1} = \sigma^{H\to ZZ^*\to 4\ell} - \sigma^1 = |1,136 - 0.757| = 0.379\ [\mathrm{fb}] \tag{5}$$

Case 2: The systematic uncertainties were subracted from the leptons' traverse momentums. **Eleven** events were observed.

$$\delta_{syst,2} = \sigma^{H\to ZZ^*\to 4\ell} - \sigma^2 = |1,136 - 2.083| = 0.946\ [\mathrm{fb}] \tag{6}$$

As the final systematic uncertainty of the cross section measurement maximum value of $\delta_{syst,1}, \delta_{syst,2}$ was taken.

$$\delta_{syst} = 0.946\ [\mathrm{fb}] \tag{7}$$

Bibliography I

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Review of the 13 TeV ATLAS Open Data release
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Aaboud, Morad and others
Measurement of inclusive and differential cross sections in the $H \to ZZ^* \to 4\ell$ decay channel in pp collisions at $s\sqrt{} = 13\,TeV$ with the ATLAS detector
http://dx.doi.org/10.1007/JHEP10(2017)132

Passon, Oliver
On the interpretation of Feynman diagrams, or, did the LHC experiments observe the Higgs to gamma gamma decay?