T 25: Higgs Physics III

Time: Tuesday 16:15–18:15 Location: KH 00.016

T 25.1 Tue 16:15 KH 00.016

Measurement of differential cross-sections in the $H \to ZZ^* \to 4\ell$ decay channel with the ATLAS Run 3 data — •Elena Cuppini[1], Sandra Kortner[1], Oliver Kortner[1], Luca Spitzauer[1], Alice Reed[2], and Tae Hyoun Park[1] — [1]Max Planck Institute for Physics — [2]University of Glasgow

The decay of the Higgs boson into a pair of Z bosons, which subsequently decay to four leptons ($H \to ZZ^* \to 4\ell$), provides a clean signature and high signal-to-background ratio for studying the properties of the Higgs boson. This allows for precise differential fiducial cross-section measurements of this decay channel.

The measurement is performed using 165 fb^{-1} of proton-proton collision data at $\sqrt{s}$ = 13.6 TeV recorded with the ATLAS detector between 2022 and 2024. This data set, for the first time, surpasses the size of the full Run 2 sample, enabling further improvement in measurement precision. The analysis minimises model dependence by employing fiducial phase-space selections that closely match the experimental acceptance, together with corrections for detector effects. The results will be compared to Standard Model predictions, with emphasis on key differential observables.

T 25.2 Tue 16:30 KH 00.016

Higgs boson production cross-section measurements in the $H \to ZZ^* \to 4l$ decay channel with the ATLAS Run 3 data — •Luca Matthias Spitzauer[1], Elena Cuppini[1], Sandra Kortner[1], Oliver Kortner[1], Tae Hyoun Park[1], and Alice Reed[2] — [1]Max-Planck-Institut for Physics, Garching — [2]University of Glasgow, Glasgow

Cross-section measurements of various Higgs boson production processes are crucial for exploring Higgs boson properties and are highly sensitive to potential physics beyond the Standard Model. The decay of the Higgs boson into a pair of Z bosons, each subsequently decaying into two leptons ($H \to ZZ^* \to 4l$), is particularly important for these measurements due to its exceptionally clean signature.

Within the framework of Simplified Template Cross Sections (STXS), exclusive regions of phase space are defined for the different Higgs boson production modes. Accurate classification of reconstructed events into the appropriate STXS Higgs production regions is essential to enhance signal sensitivity and reduce uncertainties. The latest cross-section measurements in each STXS production region are based on 165 fb^{-1} of Run 3 ATLAS data. The analysis results are presented together with improvements achieved through an optimized classification employing a new Set Transformer machine learning model, replacing the baseline Recurrent Neural Network method.

T 25.3 Tue 16:45 KH 00.016

Measurement of $H \to \gamma\gamma$ fiducial cross sections with 13.6 TeV CMS data — •Caio Daumann, Johannes Erdmann, Linus Erdmann, Jan Lukas Späh, and Maximilian Wrabetz — RWTH Aachen, Physikalisches Institut III A

The Higgs boson is of fundamental importance for the understanding of particle physics. Since its discovery in 2012, it has been studied extensively by the ATLAS and CMS collaborations. The measurement of Higgs boson production cross sections is crucial for studying deviations from the Standard Model (SM) in the scalar sector.

In this presentation, the developments and current status of the Run 3 $H \to \gamma\gamma$ fiducial cross-section measurement are presented. With the increasing amount of data collected by the CMS experiment, these measurements are able to precisely test the SM and set constraints on scenarios beyond the SM. Effective Field Theory (EFT) and light-quark Yukawa coupling interpretations of these measurements are presented.

Special emphasis is placed on the statistical analysis, interpretations, and the new methods employed. In particular, the implementation and impact of the main systematic uncertainties are discussed, which become increasingly relevant with the unprecedented amount of data provided by the LHC during Run 3.

T 25.4 Tue 17:00 KH 00.016

STXS Measurements of H → γγ Cross Sections with 13.6 TeV CMS Data — Johannes Erdmann and •Maximilian Wrabetz — III. Physikalisches Institut A, RWTH Aachen University

The discovery of the Higgs boson opened the way to test the standard model through precise measurements of its production and decay properties. As the experimental precision increases with the large Run 3 datasets, a key challenge is to design measurements that remain interpretable in the presence of potential physics beyond the standard model (BSM), while maintaining minimal dependence on theoretical assumptions.

This contribution discusses the ongoing efforts within the CMS experiment to perform Higgs boson cross-section measurements in the simplified template cross section (STXS) framework, using events in which the Higgs boson decays into a pair of photons. The analysis makes use of proton-proton collision data recorded at a centre-of-mass energy of $\sqrt{s} = 13.6$ TeV.

The STXS framework partitions Higgs production into a set of well-defined particle-level bins, characterised by the production mode and key kinematic variables. This granular binning reduces the dependence on detailed SM modelling and isolates specific regions of phase space that are particularly sensitive to potential BSM contributions. The talk will outline the analysis strategy and highlight selected methodological components, with a focus on ongoing developments.

T 25.5 Tue 17:15 KH 00.016

Combined analysis of H → γγ and H → ZZ* → 4ℓ cross sections using partial Run-3 CMS data — •Linus Erdmann, Johannes Erdmann, Jan Lukas Späh, and Maximilian Wrabetz — III. Physikalisches Institut A, RWTH Aachen University

Measurements of the Higgs boson production cross sections and decay channels are extensively studied and essential to probe possible deviations from the standard model in the scalar sector.

This presentation outlines studies towards a combined measurement of the Higgs boson production cross section in the diphoton and four-lepton decay channels with the CMS experiment. The dataset used comprises proton-proton collisions at $\sqrt{s} = 13.6$ TeV recorded during Run-3, corresponding to an integrated luminosity of 171.4 fb^{-1}. Both decay channels provide clean signatures and well-understood event topologies, which contribute to a precise determination of Higgs boson properties. Their combination increases the overall statistical precision and enables the simultaneous constraint of several Higgs boson properties. For each channel, the cross sections are measured in a fiducial phase space at particle level, which enhances model independence and minimises extrapolation uncertainties, before being extrapolated to the total phase space for the combined measurement.

These studies highlight the potential of combining different Higgs boson decay channels for a more precise determination of its production cross sections and discuss prospects for simultaneously constraining Higgs boson couplings through the joint analysis of the two channels.

T 25.6 Tue 17:30 KH 00.016

Quantum tomography using machine learning to infer incomplete information in $H \to WW^* \to \ell\nu\ell\nu$ — Carsten Burgard[1], Vince Croft[2], André Sopczak[3], •Andrii Vak[3], and Lennart Völz[1] — [1]TU Dortmund University — [2]Leiden University — [3]CTU in Prague

We present a novel experimental strategy for testing quantum entanglement in Higgs boson decays to W boson pairs at the Large Hadron Collider. Unlike theoretical approaches that rely on expectation values of Bell operators, which are highly sensitive to outliers and detector effects, we introduce a continuous formulation of the CGLMP inequality that enables standard hypothesis testing between entangled and separable states. To overcome the fundamental challenge of reconstructing invisible neutrino momenta in the $H \to WW^* \to \ell\nu\ell\nu$ channel, we employ conditional denoising diffusion probabilistic models (cDDPM), which provide unbiased, multidimensional unfolding applicable to the full measured dataset including backgrounds. We compare the performance of diffusion-based reconstruction against neural network regression and analytical methods, evaluating each through profile likelihood hypothesis tests implemented in RooFit. Our results demonstrate that the diffusion-based approach enables robust hypothesis testing of quantum entanglement in a realistic collider environment, achieving sensitivity to Bell inequality violation with existing LHC datasets.

T 25.7 Tue 17:45 KH 00.016

Constraining Effective Field Theory operators in the HZZ4l

channel with CMS — •Christian-Max Sammoray, Matteo Bonanomi, Johannes Haller, and Matthias Schröder — Institut für Experimentalphyisk, Universität Hamburg

The discovery of the Higgs boson in 2012 by the CMS and ATLAS collaborations at the CERN Large Hadron Collider (LHC) set a major milestone in confirming the predictive power of the Standard Model (SM) of particle physics. However, despite its remarkable success, it leaves several unanswered questions, and direct searches for new physics have fallen short in observing new particles that could answer them, thus hinting at the existence of new physics beyond the energy scale reachable at the LHC.

The Standard Model Effective Field Theory (SMEFT) provides a powerful framework to probe such effects indirectly by expanding the SM Lagrangian with higher order operators. In this work, we use simulated CMS data corresponding to data-taking conditions at 13.6 TeV center-of-mass energy to study SMEFT effects in the Higgs to four-lepton channel. Differential cross section measurements are used to constrain new physics within the SMEFT framework.

This talk details the derivation of the parameterization of EFT effects on both the production and decay of the Higgs boson in the four-lepton final state, and how these measurements can be used to obtain constraints on new physics through a maximum likelihood fit.

T 25.8 Tue 18:00 KH 00.016

Combined measurements of the Higgs boson at ATLAS — •Ahmed Markhoos, Benedict Winter, and Karl Jakobs — University of Freiburg, Freiburg im Breisgau, Germany

Statistical combinations provide the cutting edge results for processes that can be studied through different signatures. Notable examples at the LHC have been measurements of Higgs boson production and decays. In this talk, I present the status of the latest combination of the Higgs boson measurements, performed by the ATLAS experiment with the Run 2 dataset spanning two main subjects. The first are measurements of the overall products of the Higgs-boson cross-sections and branching ratios, as well as a measurement performed in the Simplified Template Cross-section scheme, showcasing sensitivity gains in challenging parts of the phase space that may feature first hints of physics beyond the Standard Model. The second are interpretations of these measurements with the Kappa framework, which compares the measured coupling properties with those predicted by the Standard Model, and via Effective Field theory exploring possible couplings beyond the Standard Model.