T 8: Higgs Boson: Decay in Fermions 1

Time: Monday 16:15–18:30 Location: T-H21

T 8.1 Mon 16:15 T-H21

Measurement of Higgs boson production cross sections in the di-τ decay channel with the ATLAS detector and the combination with other decay channels — •Frank Sauerburger, Karsten Köneke, Christopher Young, and Karl Jakobs — Albert-Ludwigs-Universität Freiburg, Deutschland

The coupling of the Higgs boson to τ-leptons is one of the most precisely measured couplings of the Higgs boson to fermions. A measurement of the production cross sections of the Higgs boson decaying into two τ-leptons is presented. The cross section is measured in the gluon-fusion, vector-boson-fusion, W/Z boson associated, and top-quark pair associated production channels. The study illustrates the application of machine-learning techniques. The analysis uses proton-proton collision data at a center-of-mass energy $\sqrt{s} = 13\,\text{TeV}$ corresponding to an integrated luminosity of $139\,\text{fb}^{-1}$ recorded during Run 2 with the ATLAS detector at the LHC.

In addition, the combination of this measurement with other Higgs boson production and decay channels is presented. The presentation focuses on the measurement of coupling modifiers in the κ framework.

T 8.2 Mon 16:30 T-H21

Optimization of di-tau mass reconstruction in the ATLAS experiment using a deep neural network — Klaus Desch, Philip Bechtle, Christian Grefe, Lena Herrmann, and •Ramy Hmaid — Rheinische-Friedrich-Wilhelms-Universität Bonn

A major challenge of identifying Higgs decays to tau leptons is the similarity of Higgs- and Z-Boson decays, due to their similar mass and at least least two unobservable neutrinos in the final state.

We will present a regression neural network that determines the invariant mass of the reconstructed di-tau system and compare its performance with existing solutions for this problem. In addition, the stability of the neural network response under different training conditions will be discussed.

T 8.3 Mon 16:45 T-H21

Improving the sensitivity of CP tests in VBF Higgs-boson production exploiting the $H \to \tau_e\tau_\mu$ decay with neural networks for the reconstruction of the Higgs-boson four-momentum at the ATLAS experiment — •Alexandra Spitzer, Michael Böhler, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

Violation of CP invariance is one of the three Sakharov conditions needed to explain the observed baryon asymmetry in our universe. In the Standard Model CP violation is already introduced via the CKM matrix. However, its size is not sufficient to explain the amount of observed baryon asymmetry. The vector-boson fusion production of the Higgs particle allows to study its CP structure of the couplings to electroweak gauge bosons HVV.

CP invariance of HVV couplings is probed by investigating the mean value of the CP-odd Optimal Observable. Since the Higgs bosons's four-momentum is required for calculating the Optimal Observable the resolution of the Optimal Observable is limited by the reconstruction quality of the Higgs boson's four-momentum. It is investigated how neural networks improve the reconstruction quality of the four-momentum in comparison to the Missing Mass Calculator. The hyperparameters of four different neural networks were optimized by using a hyperparameter optimization software framework OPTUNA. The impact on determing the strength of CP violation in the $H \to \tau_e\tau_\mu$ decay channel assuming $\mathcal{L} = 139$ fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV is presented.

T 8.4 Mon 17:00 T-H21

Signal selection and background estimation for testing CP invariance in vector boson fusion production of the Higgs boson in the $H \to \tau_e\tau_\mu$ decay channel using the ATLAS detector — •Ye Joon Kim, Valerie Lang, Ö. Oğul Öncel, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The combination of charge conjugation symmetry (C) and parity symmetry (P), together denoted as CP invariance, is violated in the Standard Model (SM) of particle physics in the weak interaction. The amount of CP violation in the SM is not enough to explain the observed baryon asymmetry in the universe. Further sources of CP violation may exist in the Higgs sector. The CP nature of the Higgs boson coupling to vector bosons is investigated in vector-boson fusion production (VBF) of the Higgs boson exploiting the $H \to \tau_e\tau_\mu$ decay channel.

In this talk, contributions to the search for CP violation in VBF production in the $H \to \tau_e\tau_\mu$ channel based on pp collision data collected with the ATLAS detector at $\sqrt{s} = 13$ TeV corresponding to an integrated luminosity of 139 fb^{-1} are discussed.

The estimation of background processes, in particular from events where jets are falsely identified as electrons or muons, with the data-driven matrix method is presented. Studies of the signal selection will also be shown.

T 8.5 Mon 17:15 T-H21

Signal selection and background estimation for testing CP invariance in vector boson production of the Higgs boson in the $H \to \tau_{lep}\tau_{had}$ decay channel using the ATLAS detector — •Helena Moyano, Valerie Lang, Ö. Oğul Öncel, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The existence of charge conjugation and parity symmetry (CP) violating processes represents one of the three Sakharov conditions for baryogenesis, the mechanism that explains the different abundances of matter and antimatter in the universe. The Standard Model of particle physics includes a description of CP violating processes, however, their contribution is not sufficient to explain the observed baryon asymmetry in the universe. The discovery of the Higgs boson in 2012 opened the window to search for new sources of CP violation in the production or decay of the Higgs boson.

The analysis exploits Higgs-boson production via vector-boson fusion (VBF) and the decay $H \to \tau_{lep}\tau_{had}$ to search for CP-violating contributions to the HVV vertex based on data collected by the ATLAS detector at $\sqrt{s} = 13$ TeV corresponding to an integrated luminosity of $\mathcal{L}$ =139 fb^{-1}.

This presentation discusses the selection of $\tau_{lep}\tau_{had}$ events with neural networks as well as the estimations of the background contributions. Particularly, first studies will be shown regarding the estimation of the background contribution due to jets misidentified as hadronically decaying τ leptons using the Fake Factor method.

T 8.6 Mon 17:30 T-H21

Event reconstruction techniques in the context of a Higgs boson CP analysis in the di-tau lepton final state with the CMS experiment — Wolfgang Lohmann, Achim Stahl, and •Alexander Zotz — RWTH Aachen University - Physics Institute III B, Aachen, Germany

In 2020 the first measurement of the effective CP mixing angle in Higgs boson decays into two tau leptons has been performed by the CMS experiment. It was determined to be $(4 \pm 17)^\circ$ using the Run 2 data set of pp collision of $137 fb^{-1}$ integrated luminosity. The mixing angle was extracted from a distribution of angles between the decay planes of the tau lepton decay products in the $H \to \tau\tau$ decay. In the case of hadronic tau lepton decays via the intermediate a_1 resonance the full tau lepton kinematics including its neutrino and furthermore its polarimetric vector can be reconstructed. Requiring both tau leptons to decay via a_1 mesons allows for the reconstruction of a CP sensitive observable with higher sensitivity. However the a_1a_1 final state suffers from a small branching fraction and therefore these improvements have a neglible effect on the overall sensitivity once all final states are included.

In this talk, an extension of the polarimetric vector method via the inclusion of final states with an a_1 decay on one side and a single charged lepton or hadron on the other side of the $H \to \tau\tau$ decay is presented. To reconstruct the event a kinematic fit with external constraints is used and the potential improvement on the measurement of the CP mixing angle is discussed.

T 8.7 Mon 17:45 T-H21

Tau reconstruction exploiting machine learning techniques at CMS — •Ze Chen — DESY, Hamburg, Germany

Reconstruction of hadronically decaying tau leptons (denoted as τ_h) in the CMS experiment at the Large Hadron Collider has been historically performed with the Hadron-plus-strip (HPS) algorithm. In the HPS algorithm, the τ_h final state signature is identified by combining information from charged hadrons, reconstructed by their associated tracks, and π_0 candidates, obtained by clustering photon and electron candidates in rectangular regions, called "strips". As of the LHC Run 2, deep-learning techniques have been implemented to improve the identification of genuine τ_h leptons and reduce contributions from backgrounds. This talk covers a study to improve the tau decay mode reconstruction using machine learning techniques. Its efficiency is shown and compared to the one of the HPS algorithm.

T 8.8 Mon 18:00 T-H21

Search for lepton-flavour violating decays of the Higgs boson using the symmetry method for background estimation with the ATLAS experiment at $\sqrt{s} = 13$ TeV — •Katharina Schleicher, Valerie Lang, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The discovery of the Higgs boson opened the window to a variety of interesting probes to physics beyond the standard model (SM), including searches for lepton-flavour violating (LFV) Higgs-boson decays. Such decays are predicted in several extension of the SM e.g. in models with two Higgs doublets. In nature, LFV was already observed in form of neutrino oscillations. In this analysis the decays of $H \to e\tau$ and $H \to \mu\tau$ with leptonic τ-decays leading to $e\mu + 2\nu$ final states are considered. A central part of the analysis is the precise estimation of the SM backgrounds. Therefore, a data-driven method is used - the so-called symmetry method. It exploits two principles: First, SM backgrounds with prompt leptons are symmetric w.r.t. the interchange of electrons and muons. And second, this symmetry is broken if the branching ratios of the two LFV decays are of different magnitude. The first principle implicates the challenge of restoring this symmetry since electrons and muons are experimentally different. The second principle is motivated by the upper limit on the $BR(\mu \to e\gamma)$. To obtain the best possible sensitivity, a dedicated statistical model was developed and neural networks for classification are deployed. In this talk, an overview of the analysis using the LHC Run-2 dataset recorded with the ATLAS detector in pp collisions at $\sqrt{s} = 13$ TeV is given.

T 8.9 Mon 18:15 T-H21

Sensitivity to lepton flavour violating Higgs boson decays at the HL-Lhc using data-driven background estimation — •Naman Kumar Bhalla, Katharina Schleicher, Valerie Lang, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

One of the primary goals of the Large Hadron Collider (Lhc) program is to look for processes beyond the Standard Model (SM) of particle physics. One such process predicted by many beyond-SM theories is lepton flavour violation (LFV) in the decays of the Higgs Boson. A search for LFV decays of the Higgs boson with $H \to e\tau_\mu$ and $H \to \mu\tau_e$ final states was performed using the full Run 2 data collected at $\sqrt{s} = 13\,\text{TeV}$, corresponding to an integrated luminosity of $138\,\text{fb}^{-1}$. A part of this analysis used a data-driven background estimation, which takes advantage of the idempotency of SM backgrounds under the exchange of an electron and a muon. This symmetry is then broken only by the difference in the two LFV signals considered. Due to its data-driven nature, the sensitivity of this approach is limited by statistical uncertainties, which are expected to reduce with more data.

This talk describes the extrapolation of the Run 2 analysis' sensitivity to conditions at the high-luminosity Lhc (HL-Lhc), where a data set, collected in pp collisions at $\sqrt{s} = 14\,\text{TeV}$ corresponding to an integrated luminosity of $3000\,\text{fb}^{-1}$, is expected. The extrapolation also accounts for the expected improvements in systematic uncertainties from detector upgrades planned for the HL-Lhc. The first expected sensitivities for LFV decays of the Higgs boson at the HL-Lhc, based on the data-driven background estimation, are presented.