T 68: Higgs Physics VIII (CP)

Time: Thursday 16:15–18:30 Location: ZHG105

T 68.1 Thu 16:15 ZHG105

Measurement of CP-properties of the top Yukawa coupling via $t\bar{t}H$ and tH production in the $H \to \gamma\gamma$ decay channel at CMS — Johannes Erdmann and •Florian Mausolf — III. Physikalisches Institut A, RWTH Aachen University

After the observation of the Higgs boson at the LHC and with continuing accumulation of data, its properties can be determined with increasing precision. Among these properties, the strength of the couplings to fermions and the CP-properties of its interactions are of particular importance. The top-quark Yukawa coupling, the Higgs boson's strongest interaction with fermions, plays a central role in theory and experiment. While a purely CP-odd structure has been experimentally excluded, the possibility of a significant CP-odd admixture remains consistent with current LHC constraints. A CP-odd component would influence both the cross-sections and kinematics of top-quark-associated Higgs production processes, $t\bar{t}H$ and tH. For example, the tH cross-section would increase significantly with the inclusion of a sizeable CP-odd component.

This talk presents the strategy and ongoing developments for a measurement of $t\bar{t}H$ and tH production cross sections and the CP-properties using events where the Higgs boson decays into two photons. A particular emphasis is placed on a novel approach to separate $t\bar{t}H$ and tH production processes, enabling individual $t\bar{t}H$ and tH cross-section measurements without relying on strong assumptions about CP-even and CP-odd coupling modifiers.

T 68.2 Thu 16:30 ZHG105

Machine Learning for Top-Associated Higgs Production: Probing CP Structure with Neural Simulation-Based Inference — •Stefan Katsarov, Stephen Jiggins, and Judith Katzy — Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

The Standard Model (SM) predicts that the CP structure of the fermionic Higgs couplings is CP even. However, experimentally, a CP odd component is not yet fully excluded. Detecting an additional CP odd coupling would provide direct evidence of physics beyond the SM, with significant implications, such as explaining the baryon asymmetry in the universe. The CP structure can be directly measured in top-associated Higgs production processes (ttH and tH). However, this measurement is very challenging due to the extreme rarity of these production modes and the presence of irreducible backgrounds. I will demonstrate how Neural Simulation-Based Inference (NSBI), a novel machine-learning technique, can aid this measurement, presenting the first results of research in this direction.

T 68.3 Thu 16:45 ZHG105

Test of CP invariance in Higgs boson production via vector boson fusion exploiting the $H \to \tau_{\mathbf{had}}\tau_{\mathbf{had}}$ decay mode — •Daniel Bahner, Lorenzo Rossini, and Markus Schumacher — Albert-Ludwigs-Universität, Freiburg, Deutschland

The observed baryon asymmetry in the universe can be explained if the three Sakharov conditions are fulfilled. The violation of the CP invariance is one of them. The magnitude of CP violation encoded in the Standard Model is not enough to explain the observed asymmetry via electroweak baryogenesis. Through precision measurements of the properties of the Higgs boson, additional sources of CP violation might be found. One candidate is the vector-boson fusion (VBF) production mode of the Higgs boson. In the VBF production process, it is possible to probe CP-violating contributions to the HVV coupling vertex.

This talk is focused on the VBF Higgs boson production mode with a subsequent decay into two hadronically decaying tau leptons. The CP-odd optimal observable is used in a profile-likelihood fit to perform a test of CP invariance and to constrain the strength of new CP-violating interactions. The talk will discuss the analysis strategy, CP-odd observables, and preliminary results based on $\sqrt{s} = 13\,\text{TeV}$ proton-proton collision data collected by the ATLAS detector with $\mathcal{L}_{\text{int}} = 140.1\,\text{fb}^{-1}$.

T 68.4 Thu 17:00 ZHG105

Search for CP violation in the tau Yukawa coupling with CMS Run 3 data — •Mathilde Witt[1,2], Andrea Cardini[3], Elisabetta Gallo[2], Anne-Catherine Le Bihan[1], Océane Poncet[1], Alexei Raspereza[2], Gourab Saha[1], and Stepan Zakharov[2] — [1]Institut pluridisciplinaire Hubert Curien, Strasbourg, France — [2]Deutsches Elektronen-Synchrotron, Hamburg. Germany — [3]Universidad de Oviedo, Oviedo, Spain

Following the discovery of the Higgs boson in 2012 by the ATLAS and CMS Collaborations, studies are required to investigate its Charge-Parity (CP) properties in the Yukawa interaction with tau leptons. This talk presents an ongoing master's thesis in the μa_1 decay channel. Different reconstruction techniques are implemented in the μa_1 channel to enhance the sensitivity to the CP properties of the Higgs boson to investigate whether its properties are CP-even, CP-odd, or CP-mixed. The a_1 channel denotes the decay $\tau \to \nu_\tau \pi\pi\pi$. The data were collected with the CMS detector during 2022-2023 at $\sqrt{s} = 13.6\,\text{TeV}$, corresponding to an integrated luminosity of $63\,\text{fb}^{-1}$

T 68.5 Thu 17:15 ZHG105

Construction and investigation of optimal observables for testing $\mathcal{CP}$ invariance in the decay $H \to \tau^+\tau^-$ at the LHC — •Yann Stoll, Heidi Rzehak, and Markus Schumacher — Albert-Ludwigs-Universität, Freiburg

Since the discovery of the Higgs boson, one of the most important tasks in particle physics is to measure all of its properties as precisely as possible. The Higgs boson does not only play a crucial role in understanding electroweak symmetry breaking but might also be connected to, and thus hint towards, physics beyond the Standard Model. One desirable feature of a more complete model of particle physics is additional $\mathcal{CP}$ violation in order to allow for electroweak baryogenesis.

A possibility to introduce additional $\mathcal{CP}$ violation is that the physical Higgs boson is not a $\mathcal{CP}$-eigenstate but an admixture. In this work it is investigated whether the sensitivity of $\mathcal{CP}$-tests in the decay $H \to \tau^+\tau^-$ at the LHC can be improved by using the method of optimal observables. An outline of the construction of said observables, as well as studies of their sensitivity using simulated signal events only, will be presented.

T 68.6 Thu 17:30 ZHG105

Measurements of $H \to \tau\tau$ properties at FCC-ee — •Sofia Giappichini, Jan Kieseler, Markus Klute, Matteo Presilla, Aaron Wiedl, and Xunwu Zuo — KIT, Karlsruhe

The Future Circular Collider (FCC) stands at the forefront of the European Strategy for Particle Physics as the future Higgs factory. The $H \to \tau\tau$ decay, featuring a large branching ratio, clean identification at FCC-ee environment, and the possibility to reconstruct polarization information, is an excellent channel to measure Higgs properties. The CP nature of the Htautau coupling is of particular interest because the CP-odd component only appears in Higgs gauge couplings through loop effects, while it is allowed to be sizable in the Higgs couplings to fermions. This contribution shows recent progress in the experimental setup for the $H \to \tau\tau$ analysis and reports prospective results in both the ZH, $H \to \tau\tau$ cross section measurement and CP measurement, as well as the interpretation framework based on SM effective field theory.

T 68.7 Thu 17:45 ZHG105

Probing $\mathcal{CP}$ violation in the top-Yukawa coupling at future colliders — •Vincent Riechers[1], Marco Menen[1,2], Elina Fuchs[1,2,3], and Henning Bahl[4] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig — [3]Deutsches Elektronen-Synchrotron DESY, Hamburg — [4]Institut für Theoretische Physik, Universität Heidelberg

The $\mathcal{CP}$-violating effects within the Standard Model (SM) are not sufficient to explain the observed baryon asymmetry of the Universe. Additional CP violation beyond the SM could be present in the Higgs boson couplings to other SM particles. The top-Yukawa coupling is of particular interest, as it is both the largest and most accessible Higgs-fermion interaction at the LHC and is expected to show the largest $\mathcal{CP}$-violating effects in many BSM models. The goal of this study is to evaluate the constraints that future colliders could impose on the $\mathcal{CP}$ structure of the Higgs-top coupling. While a future e^+e^- collider benefits from a very clean background, which allows precise measurements of final states with many quarks, a proton-proton collider like the FCC-hh offers a high luminosity and center-of-mass energy. We use a machine learning approach to distinguish between $\mathcal{CP}$-even and

$\mathcal{CP}$-odd events, enhancing sensitivity to potential deviations from the SM.

T 68.8 Thu 18:00 ZHG105

Symbolic Regression for Higgs CP analyses — •Marco Menen[1,2], Henning Bahl[3], Elina Fuchs[1,2], and Tilman Plehn[3] — [1]Institut für Theoretische Physik, Universität Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt Braunschweig, Germany — [3]Institut für Theoretische Physik, Universität Heidelberg, Germany

Additional sources of CP violation beyond those in the Standard Model are needed to produce a sufficient baryon asymmetry of the Universe during baryogenesis. The Higgs sector is an intriguing candidate for such sources and could provide CP violation in the Higgs couplings to fermions and gauge bosons. Recently, much work has been put into optimizing probes of CP violation with machine learning techniques. While such analysis usually outperform analyses of individual observables, the techniques used can be potentially hard to interpret accurately. We demonstrate how different approaches of Symbolic Regression can be used to obtain analytical formula. We then apply our approaches to various steps of a CP analysis, such as the signal-background classification, the classification of the CP state, or the reconstruction of a parton-level observable.

T 68.9 Thu 18:15 ZHG105

CP violation in Standard Model extensions with a Higgs singlet — Greta Bösinger[1], •Lana Dambacher[1], and Heidi Rzehak[2] — [1]Institut für Theoretische Physik, Universität Tübingen — [2]Physikalisches Institut, Universität Freiburg

In order to explain the asymmetry of matter and antimatter in our universe, a particle-physics model must contain sources of CP violation. Since the amount of CP violation provided by the Standard Model (SM) is not sufficient for this explanation, we are looking for extensions of the SM that include further sources of CP violation.

One of the simplest extensions of the SM is an extension with a complex Higgs $SU(2)_L$ singlet. The singlet leads to a more involved Higgs potential, but otherwise does not couple to any other field. This results in some freedom in the definition of its CP transformation and therefore to no new CP violation. This freedom is reduced by coupling the singlet to a vector fermion, which creates the possibility of spontaneous or explicit CP violation.

In this talk the complex Higgs singlet extension with its possible CP properties is discussed.