T 32: Higgs Physics IV

Time: Tuesday 16:15–18:30 Location: KH 01.019

T 32.1 Tue 16:15 KH 01.019

Preparation of Higgs boson STXS measurements in the $H \to \tau\tau$ decay, based on LHC Run-3 data taken with the CMS Experiment — •Sofia Giappichini, Roger Wolf, Markus Klute, and Günter Quast — Karlsruher Institut für Technologie, Institut für Experimentelle Teilchenphysik, Karlsruhe, Deutschland

This analysis presents measurements of Higgs boson production in the $\tau\tau$ decay channel. The study uses proton-proton collision events collected by the CMS experiment at the CERN LHC between 2022 and 2025, at a center-of-mass energy of 13.6 TeV, with a total integrated luminosity of 287 fb^{-1}. Focusing on both gluon fusion and vector boson fusion production modes, measurements of the signal strengths and cross-sections times branching fraction within the simplified template cross-section scheme are presented. These results provide precise sensitivity to Higgs boson production at high transverse momentum and to event topologies featuring jets.

T 32.2 Tue 16:30 KH 01.019

Newest developments and validation of the τ-embedding method for the estimation of genuine $\tau\tau$ backgrounds for $H \to \tau\tau$ analyses of CMS — •Sebastian Kaiser, Christian Winter, Roger Wolf, Günter Quast, and Markus Klute — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

The τ-embedding method, used to estimates all backgrounds with genuine τ lepton pairs in an event, is one of the main pillars for a number of precision measurements in the $H \to \tau\tau$ decay channel, of CMS. For this method events with two muons are selected, in data. All energy deposits associated to these muons during reconstruction, are removed from the event record and replaced by the energy deposits of simulated τ lepton decays with the same kinematic properties. The presentation will summarize the method itself and report on the steps undertaken to validate it for the upcoming LHC Run-3 analyses.

T 32.3 Tue 16:45 KH 01.019

Re-analysis of the LHC Run-2 data taken with the CMS Experiment in view of a combined LHC Run-2 + Run-3 measurement of Higgs boson STXS measurements in the $H \to \tau\tau$ decay channel — •Tamara App, Artur Monsch, Markus Klute, Günter Quast, and Roger Wolf — KIT, Karlsruhe, Germany

A re-analysis of LHC Run-2 data of the year 2018, after a complete re-reconstruction performed by the CMS Collaboration, in view of an anticipated combined Run-2 + Run-3 measurement of Higgs boson STXS measurements in the $H \to \tau\tau$ decay channel is presented. The level of data understanding is demonstrated indicating the transition towards high precision measurements and the perspective of a future measurement based on a systematic uncertainty aware neural network training is given.

T 32.4 Tue 17:00 KH 01.019

ML-driven Di-Tau Mass and Momentum Reconstruction at the ATLAS Detector — •Jonathan Pampel, Tatjana Lenz, and Jochen Dingfelder — University of Bonn

A common process in particle physics analyses is the decay of a neutral particle into two tau leptons. Each tau lepton decay contains at least one neutrino, making the reconstruction of the 4-momentum – and in particular, the mass – of the neutral particle an underdetermined problem.

In this work, a neural network has been trained on ATLAS γ^* Monte Carlo samples at $\sqrt{s} = 13.6$ TeV to estimate the di-tau system's 4-momentum, using the reconstructed visible tau 4-momenta and the missing transverse momentum as input features.

This talk presents the development of the neural network and its performance in comparison to the Missing Mass Calculator (MMC), the previously established tool for di-tau 4-momentum reconstruction.

T 32.5 Tue 17:15 KH 01.019

Higgs Boson Mass Reconstruction in the Analysis of $tH(\tau\tau)$ Production with ATLAS Run-2 Data — Jiri Javora[1], •Christian B. Hughes[1], Chalaka Fernando[2], and André Sopczak[1] — [1]CTU in Prague — [2]CERN

The latest results on the mass reconstruction in the analysis $tH(\tau\tau)$ are presented with focus on machine learning using ATLAS Run-2 data.

T 32.6 Tue 17:30 KH 01.019

Estimate of the contribution from jets misidentified as hadronic tau decays using normalizing flows — •Matthias Moser, Tamara App, Nikita Shadskiy, Artur Monsch, Markus Klute, Günter Quast, and Roger Wolf — KIT, Karlsruhe, Germany

For H $\to \tau\tau$ analyses, the most accurate estimation of the background originating from falsely identified hadronic τ decays remains a major challenge. To estimate this background from data, we employ the fake-factor method, in which the rate of misidentified τ candidates is obtained from a Determination Region, which is maximally pure in a given background process, and then applied in an Application Region to determine the rate of misidentified tau candidates in the desired Signal Region.

The resulting F_{F} transfer function exhibits non-trivial dependencies on several variables, which are difficult to model using conventional techniques. It can be shown that these dependencies are determined by the probability density functions (p.d.f.) of events in the Application and Signal Regions. These p.d.f.'s can be learned with neural-networks, like e.g., normalizing flows. While the training procedure may be computationally intensive, the evaluation of the p.d.f.'s after training is fast. This approach provides an efficient and scalable description of the multi-variable dependence of the F_{F} transfer function.

T 32.7 Tue 17:45 KH 01.019

Construction and investigation of optimal observables for testing 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 Higgs boson's discovery, a central objective in particle physics has been the precise determination of its properties. Beyond its key role in electroweak symmetry breaking, the Higgs sector may also provide clues to physics beyond the Standard Model.

In particular, extended models that aim to support electroweak baryogenesis require additional sources of CP violation, which could arise if the Higgs boson is not a CP eigenstate but a CP-mixed state. In the Higgs-tau-tau vertex the strength of CP violation can be parameterized by a single parameter ϕ_{CP}. This talk examines whether the CP-sensitivity in the decay $h \to \tau^+\tau^-$ at the LHC can be enhanced through the use of optimal observables. The tau-lepton decay modes $\tau^\pm \to (\pi^\pm\nu), (\pi^\pm\pi^0\nu)$ and $(l^\pm\nu\nu)$ are considered. We will outline the construction of these observables and present a sensitivity study based on simulated signal samples. This study is based on the past analysis by the ATLAS collaboration using the Run-2 data set collected at a centre-of-mass energy of 13 TeV, in the sense that we use a comparable event selection and categorization.

T 32.8 Tue 18:00 KH 01.019

Test of CP invariance of the Higgs-strahlungs process $pp \to V \to VH$ exploiting the $H \to \tau\tau$ and $V \to jj$ decay mode with the ATLAS detector — •Frederik Schulz, Lorenzo Rossini, and Markus Schumacher — Albert-Ludwigs-Universität, Freiburg, Deutschland

One open question in cosmology is the origin of the observed baryon asymmetry in our universe. This asymmetry can be explained if the three Sakharov conditions are fulfilled. One of these conditions includes the violation of the invariance under combined charge (C) and parity (P) conjugation. However, the magnitude of CP effects predicted in the Standard Model (SM) is not large enough to explain the size of the observations. The Higgs boson is a promising candidate for investigating possible CP-violating interactions, particularly in the coupling vertex with vector bosons (HVV).

In this talk, the focus will be on the Higgs-strahlung production mode (VH), with a subsequent decay of the Higgs boson into two hadronically decaying tau-leptons, and the V boson also decaying hadronically. Preliminary studies for an analysis based on the proton-proton data collected by the ATLAS experiments at a center of mass energy of $\sqrt{s} = 13.6$ TeV during Run 3 will be presented. The analysis is based on the measurement of the CP-odd optimal observable. A profile-likelihood fit is performed to extract the expected sensitivity to

CP-sensitive EFT models, such as SMEFT.

T 32.9 Tue 18:15 KH 01.019

Machine Learning to search for the CP violation of the Higgs boson in $H \to \tau\tau$ decays at ATLAS — •Laney Klipphahn, Philip Bechtle, Klaus Desch, Christian Grefe, and Timo Saala — University of Bonn

Reconstruction at ATLAS has been evolving throughout the past decades. Especially machine learning (ML) techniques have been implemented to support and replace individual steps in the reconstruction chain. With these powerful methods, the question arises, to what extend Machine learning models can learn and reproduce the complex calculations that map detector signals to high-level physics observables?

A particularly interesting challenge for ML is the study of CP violation of the Higgs boson in $H \to \tau\tau$ decays. The CP property of the Higgs is closely linked to one of the unsolved questions in physics, namely the matter and anti-matter asymmetry observed in the universe today. While the pure CP-odd state has been excluded by measurements, the CP-even or CP-mixed property of the Higgs has yet to be confirmed experimentally. In the Higgs-Yukawa coupling the CP-violation is accessible from the angular correlations of the decay products, which depend on the decay mode of the τ leptons in the $H \to \tau\tau$ decay. The CP-property is then obtained by a non-trivial combination of multiple observables in the final state. In this talk I will present the studies on ML for the CP violation of the Higgs boson to assess whether ML models can reach similar or better accuray than traditional reconstruction algorithms.