# T 62: Higgs Boson: Extended Models 2

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

T 62.1 Wed 16:15 T-H21

**Combined measurements of Higgs boson production and interpretation in the context of two Higgs doublet models at the ATLAS experiment** — •Birgit Stapf — Universität Hamburg/DESY, Hamburg, Germany

The discovery of the Higgs boson in 2012 is the latest big success story of the Standard Model of particle physics (SM). Although this discovery formally completes the SM, it is not an end to all questions on the matter. There are many observations and phenomena that the SM is unable to explain, and it is clear that there must be Beyond the Standard Model (BSM) physics. However, the lack of discoveries of (BSM) particles since 2012 puts particle physics at a cross-roads: there are many ways forward, posed by many different BSM theories, but it is unclear which one is likely to be successful as a description of reality. High precision measurements of the Higgs bosons' properties and its couplings help to guide the way: any measured deviation from the SM predictions indicate the existence of BSM physics and may even point at specific theories. To unlock the full potential of such measurements, the results from analyses of several different Higgs production processes and decays are combined. This talk covers the latest Higgs combination results from ATLAS using up to 139 fb$^{-1}$ of $pp$-collision data with $\sqrt{s}$=13 TeV, focussing in particular on the measurement of inclusive production cross-sections and the interpretation in terms of specific BSM models, such as two Higgs doublet models.

T 62.2 Wed 16:30 T-H21

**Search for charged Higgs bosons in the $H^+ \to Wh \to qqbb$ decay channel** — •Shubham Bansal, Jochen Dingfelder, and Tatjana Lenz — Physikalisches Institut, Universität Bonn

After the discovery of the Higgs boson at a mass of 125 GeV, the last missing piece of the Standard Model (SM) might be found. On the other hand, various theories beyond the SM predict additional Higgs bosons, one of which could be the found Higgs boson at 125 GeV. One such example is the two-Higgs-Doublet Model (2HDM) that features an extended scalar sector including the existence of charged Higgs bosons ($H^+$). The observation of such a charged scalar particle would clearly indicate physics beyond the SM. The $H^+$ production mechanism depends on its mass ($m_{H^+}$) and for $m_{H^+} > m_t + m_b$, the leading $H^+$ production mode is the associated production with a top and a bottom quark via $gg \to tbH^+$. In the alignment limit for 2HDM, the dominant decay mode is $H^+ \to tb$. However, in models like N2HDM and the Georgi-Machacek (GM) model, it is possible to obtain a sizable branching ratio for $H^+ \to Wh$.

This talk presents a search for charged Higgs bosons in $H^+ \to Wh \to qqbb$ decays. The recent developments of the analysis strategy will be discussed, which include the use of boosted decision trees to reconstruct the $H^+$, data-driven corrections to improve the modeling of the main background, $t\bar{t}$, the definition of signal-enriched and -depleted regions, and a first estimate of the expected sensitivity using the full Run-2 ATLAS dataset.

T 62.3 Wed 16:45 T-H21

**Search for a charged Higgs Boson decaying to $cs$ in the low mass region with the ATLAS detector at $\sqrt{s} = 13$ TeV** — Jochen Dingfelder, Tatjana Lenz, and •Christian Nass — Physikalisches Institut, Universität Bonn, Deutschland

In the Standard Model (SM) electroweak symmetry breaking (EWSB) is introduced by a single complex scalar field. The consequence is the prediction of a scalar, neutrally charged particle, the Higgs Boson, which was discovered at the LHC in 2012 at the LHC. A simple extension of the SM is to introduce EWSB through two complex scalar fields. Such two-Higgs doublet models (2HDM) are attractive because they offer the opportunity to include additional CP violation in the SM, which is needed for explaining baryogenesis. 2HDMs feature 3 neutral and 2 charged Higgs bosons. Observation of such a charged scalar would be a striking signal for physics beyond the SM.

In the low mass region, i.e. $m_H^{\pm} < m_t$, the dominant production mode is by a $t\bar{t}$ pair with one $t$-quark decaying to $H^{\pm}b$. At low masses, the search for $H^{\pm} \to cs$ decays is promising, as suggested in several theory papers. This talk will present background estimates, data-driven MC corrections and usage of c-tagging to define signal enriched and depleted regions as well as the first estimate of the expected sensitivity for the $H^{\pm} \to cs$ search with the full Run-2 ATLAS dataset recorded at a center-of-mass energy of 13 TeV.

T 62.4 Wed 17:00 T-H21

**Search for $A \to ZH \to \nu\bar{\nu}b\bar{b}$ at $\sqrt{s} = 13$ TeV with the ATLAS detector** — •Ilia Kalaitzidou, Tetiana Moskalets, and Spyridon Argyropoulos — University of Freiburg

The extension of the scalar SM Higgs sector, as described in the Two Higgs Doublet Models (2HDMs), could lead to a cosmological first order electroweak phase transition, which is necessary to explain the origin of the matter-antimatter asymmetry in the early Universe. The existence of a second Higgs doublet results in five physical scalar fields, two charged ($H^{\pm}$), a CP-odd ($A$) and two CP-even ($h$ and $H$) neutral fields. A strong electroweak phase transition favours a heavy CP-odd scalar state $A$, together with a large mass splitting between the CP-odd $A$ and CP-even $H$ scalars. In this scenario, the $A \to ZH$ decay becomes dominant. In the present work, the $A \to ZH$ decay is investigated, with the $H$ boson decaying to a pair of $b$-quarks and the $Z$ boson decaying to neutrinos. The $Z \to \nu\bar{\nu}$ decay is examined, because of the expected increased sensitivity for large $A$ masses. The optimisation studies for the $A \to ZH \to \nu\bar{\nu}b\bar{b}$ analysis are presented, along with the expected exclusion in the $m_H - m_A$ plane, covering a previously unexplored region.

T 62.5 Wed 17:15 T-H21

**Search for $A \to ZH \to \ell\ell t\bar{t}$ at $\sqrt{s} = 13$ TeV with the ATLAS detector** — •Roman Kuesters, Tetiana Moskalets, and Spyros Argyropoulos — University of Freiburg, Freiburg im Breisgau, Germany

The generation of the matter-antimatter asymmetry in the universe is one of the biggest open questions that require physics beyond the Standard Model. An attractive explanation is provided by the electroweak baryogenesis models, which require the addition of a second Higgs doublet, giving rise to five Higgs bosons: a light (heavy) $CP$-even Higgs $h(H)$, a $CP$-odd one ($A$) and two charged ones ($H^{\pm}$). A necessary requirement for baryogenesis is a large mass splitting between the heavy $CP$-odd and $CP$-even Higgs bosons, which makes the $A \to ZH$ decay dominant.

This talk presents a search for the $A \to ZH \to \ell\ell t\bar{t}$ process, targeting the phase space with $m_H > 350$ GeV, which has not been explored so far. The talk will discuss the optimisation of the event selection and the sensitivity expected to be achieved with the full Run 2 ATLAS data.

T 62.6 Wed 17:30 T-H21

**Search for heavy Higgs bosons in the $Zt\bar{t}$ final state with CMS** — •Daniel Christian Hundhausen, Ksenia de Leo, Yannick Fischer, Johannes Haller, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

Since its discovery in 2012 the properties of the Higgs boson at 125 GeV have been studied extensively, confirming a standard model like behavior. However, the observed resonance might well be part of an extended Higgs sector, which is predicted in various scenarios of new physics beyond the standard model. Two Higgs Doublet Models (2HDM) provide a generic description of the phenomenology arising in models with a second Higgs doublet. In this talk we will investigate the hypothetical decay of a CP odd heavy Higgs boson $A$ decaying into a CP even heavy Higgs boson $H$ and a $Z$ boson, with the $H$ decaying further into a pair of top quarks. This decay channel is particularly relevant in the high mass and low $\tan(\beta)$ regime. We will present the strategy and status of our analysis, targeting the fully hadronic $t\bar{t}$ decay with the $Z$ boson decaying to $\mu^+\mu^-$.

T 62.7 Wed 17:45 T-H21

**Search for heavy Higgs bosons in the $Z + t\bar{t}$ final states with CMS** — •Yannick Fischer, Ksenia de Leo, Johannes Haller, Daniel Hundhausen, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

Since its discovery in 2012, the properties of the Higgs boson at 125 GeV have been studied in numerous measurements. Within the uncertainties all results suggest a Standard Model like behaviour. However, the observed boson might well be part of an extended Higgs sector,

which is predicted in various scenarios of new physics beyond the standard model. Two Higgs Doublet Models (2HDM) provide a generic description of the phenomology arising in models with a second Higgs doublet. In this talk we will investigate the hypothetical decay of a CP odd heavy Higgs boson $A$ decaying into a CP even heavy Higgs boson $H$ and a $Z$ boson, with the $H$ decaying further into a pair of top quarks. This decay channel is particularly relevant in the high mass and low $\tan(\beta)$ .We will give an overview about the parameter space with detailed phenomenological studies, the results of the investigations of the kinematic properties of the decay products and present first expected exclusion limits in the decay channel $Z \to \mu^+\mu^-$ and $t\bar{t} \to$ jets.

T 62.8 Wed 18:00 T-H21

**Search for light pseudoscalar boson pairs produced from decays of the 125 GeV Higgs boson in final states with tau leptons** — •Lakshmi Pramod — DESY

An extended Higgs sector is well-motivated in several Beyond the Standard Model theories. A vast set of models containing two Higgs doublets plus one additional Higgs singlet complex field (2HD+1S) are consistent with SM measurements, constraints from searches for additional Higgs bosons and supersymmetry, as well as with the measured properties of the H(125) boson. The Higgs sector of the 2HD+1S models contains seven physical states: three CP-even, two CP-odd and two charged bosons. In the context of these models, the H(125) boson can decay into a pair of light pseudoscalar bosons ($a_1$), which can subsequently decay to pairs of Standard Model particles. There exist scenarios where $a_1$ can have an enhanced decay rate to a pair of $\tau$ leptons. A search for a pair of light bosons, $a_1$, produced from decays of 125 GeV Higgs boson, each decaying to a pair of $\tau$ leptons will be presented. The search is based on proton-proton collision data collected by the CMS experiment during Run 2 at a centre of mass energy of 13 TeV, corresponding to an integrated luminosity of 138 $fb^{-1}$ . Model-independent upper limits at 95% confidence level on the 125 GeV Higgs boson production cross-section times the branching fraction into the studied final state, relative to the SM H(125) production cross-section, are set. Model-specific upper bounds obtained as constraints on the parameter space of the different benchmark scenarios within the 2HDM+S will also be presented.

T 62.9 Wed 18:15 T-H21

**Search for a light CP-odd Higgs boson decaying into a pair of taus with ATLAS** — •Jannik Friese, Tom Kresse, Max Märker, Wolfgang Mader, and Arno Straessner — IKTP, Dresden, Germany

Even though theoretical predictions of the SM are corresponding to experimental results to an incredible degree, there are still some phenomena unexplained, for example the deviation of the measured anomalous magnetic moment, $g-2$, of the muon from SM calculations. This deviation could be explained by the flavor-aligned two-Higgs-doublet model (2HDM). The introduction of a second Higgs doublet leads to four additional Higgs bosons, one of which being CP-odd and electrically neutral. The muon $g-2$ deviation is best explained with a light CP-odd Higgs boson which couples nearly exclusively to top quarks and tau leptons. This talk presents the search of such a light CP-odd Higgs boson produced via gluon fusion. The decay into two tau leptons is analyzed by looking at one electron and one muon in the final state. The mass of the light Higgs boson is assumed to be in the range between 40 GeV and 90 GeV. The search is based on 139 $fb^{-1}$ of data collected by the ATLAS experiment at 13 TeV center of mass energy. Before unblinding the signal region, background control regions are analyzed to verify a good description of the data distributions. In particular, the transverse momentum spectrum of the electrons and muons receives contributions from QCD background which is not modeled well by Monte Carlo simulations. This talk focuses on the estimation of this source of background using a data driven fake-factor method.