Higgs potential and BSM opportunity 希格斯物理研讨会

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南京大学（鼓楼校区）线上会议 Nanjing University (Gulou Campus)
at ZOOM

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Probing electroweak phase transition with multi-TeV muon colliders and gravitational waves

Authors: Ke-pan Xie[1]; Wei Liu[2]

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We study the complementarity of the proposed multi-TeV muon colliders and the near-future gravitational wave (GW) detectors to the first order electroweak phase transition (FOEWPT), taking the real scalar extended Standard Model as the representative model. A detailed collider simulation shows the FOEWPT parameter space can be greatly probed via the the vector boson fusion production of the singlet, and its subsequent decay to the di-Higgs or di-boson channels. Especially, almost all the parameter space yielding detectable GW signals can be probed by the muon colliders. Therefore, if we could detect stochastic GWs in the future, a muon collider could provide a hopeful crosscheck to identify their origin. On the other hand, there is considerable parameter space that escapes GW detections but is within the reach of the muon colliders. The precision measurements of Higgs couplings could also probe the FOEWPT parameter space efficiently.

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Selected results in the 3HDMs

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New Physics can manifest itself at colliders in the form of a non-minimal Higgs sector. In particular, the Higgs doublets can also come in generations leading to rich phenomenology. In this talk, I will give a brief overview of the three-Higgs-doublet models (3HDM) focusing on novel model-building opportunities, which go beyond the well studied 2HDM case. I will highlight some recent results related to novel symmetries and their consequences.

Summary:

New Physics can manifest itself at colliders in the form of a non-minimal Higgs sector. In particular, the Higgs doublets can also come in generations leading to rich phenomenology. In this talk, I will give a brief overview of the three-Higgs-doublet models (3HDM) focusing on novel model-building opportunities, which go beyond the well studied 2HDM case. I will highlight some recent results related to novel symmetries and their consequences.

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Probing the electroweak symmetry breaking with Higgs production at the LHC

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The electroweak symmetry breaking (EWSB) mechanism is still an undecided question in particle physics. We propose to utilize the single top quark and Higgs associated production (th), Zh production via gluon fusion at the LHC to probe the couplings between the Higgs and the gauge bosons and further to test the EWSB. We demonstrate that the th and $gg \to Zh$ productions are sensitive to the relative sign of couplings ($ht\bar{t}$, hWW) and ($ht\bar{t}$, hZZ), respectively. We find that the relative sign between hWW and hZZ couplings could be fully determined after combining the present measurements from $gg \to h$, $t\bar{t}h$ and the th, Zh channels at the 13 TeV LHC, and this conclusion is not sensitive to the possible new physics contribution induced by $Zt\bar{t}$ couplings in the $gg \to Zh$ production.

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Affleck-Dine Leptogenesis from Higgs Inflation

Author: Chengcheng Han[1]

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I will present a simple extension of the Standard model to explain the origin of inflation, baryon asymmetry and neutrino masses at the same time.

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Measurement of the CP property of the Higgs to top Yukawa coupling

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Probing the B+L violation process with the observation of cosmic magnetic field

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We numerically investigate the B+L violation process by performing three-dimensional lattice simulations of a unified scenario of first-order phase transitions and the sphaleron generation. The simulation results indicate that the Chern-Simons number changes along with the helical magnetic field production when the sphaleron decay occurs. Based on these numerical results, we then propose a novel method to probe the baryon asymmetry generation of the Universe, which is a general consequence of the electroweak sphaleron process, through the astronomical observation of corresponding helical magnetic fields.

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Search for heavy Higgs decaying to two tau leptons with the ATLAS detector using pp collision at sqrt(s) = 13 TeV

Author: 瀚非叶 [1]

Co-authors: Lei Zhang [1]; Xiaozhong Huang [2]

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[2] *NJU*

This talk will cover the latest result of searching for heavy Higgs decaying to two tau leptons with the ATLAS full Run2 datasets using pp collison at $\sqrt(s)$ = 13 TeV. This search is performed over the mass range of 0.2-2.5 TeV and the two τ leptons decay is considered, where at least one τ decays leptonically. This channel is sensitive at high $\tan\beta$ value acoording to hMSSM and other 2HDMs, where $\tan\beta$ is the ratio of the vacuum expectation values of the two Higgs. The results of this search show that most of the parameter space of hMSSM is excluded with 95% CL.

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Probing Higgs boson properties with boosted objects at the CMS experiment

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Advances in boosted jet tagging techniques, particularly with novel machine learning approaches, have led to significant performance improvements in the reconstruction and identification of the hadronic decays of the Higgs boson and provided additional handles to probe the Higgs boson properties at the LHC. In this talk, I will present recent progress in machine learning-based methods for boosted Higgs boson reconstruction and discuss their applications in recent CMS searches, e.g., the H->cc decay and the VBF Higgs pair production.

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Search for Resonant and Non-resonant VHH Production with ATLAS detector

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A search for a vector boson produced in addition to two SM Higgs bosons is studied. Three different models are considered either non-resonant production with SM-like or non-SM-like Higgs self-coupling and hhVV coupling, or resonant production in the form of either VH(hh) or A→ZH(hh). Three sub-channel is considered for different decay mode for vector boson to Zll/Wlv/Zvv final states. Only HH->bbbb decay is considered for statistics and high signal efficiency.

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Probe BSM physics with the interaction between the Higgs boson and top quark

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The top quark is the heaviest elementary particle, studying its interaction with the Higgs boson not only helps to further understand the newly discovered Higgs boson itself, but also opens new opportunities to probe the BSM physics. This talk will summarize recent new experimental results that connect the top-Higgs interaction with searches of new physics beyond the standard model with the LHC Run 2 dataset.

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All order nonfactorizable jet veto effects in Higgs boson production

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I will discuss nonfactorizable QCD corrections from central jet veto to Higgs boson production at the Large Hadron Collider. At hadron colliders, phase factors in the scattering amplitudes lead to double-logarithmic corrections starting at four-loop order. I will introduce our recent work on the first all-order structure of these "super-leading" logarithms. Our analysis shows that in certain kinematic distributions the nonfactorizable corrections can be as large as a percent making them quite comparable to their factorizable counterparts.

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Search for Higgs boson pair production in □□□□ final state

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Searches are performed for non-resonant and resonant di-Higgs boson production in the □□-□□ final state. The data set used corresponds to an integrated luminosity of 139 fb−1 of proton–proton collisions at a center-of-mass energy of 13 TeV recorded by the ATLAS detector at the CERN Large Hadron Collider. No excess with respect to background expectations is found and upper limits on the di-Higgs boson production cross sections are set. A 95% confidence level upper limit of 130 fb is set on the □□ → □□ non-resonant production, where the expected limit is 180 fb. The observed (expected) limit corresponds to 4.1 (5.5) times the cross section predicted by the Standard Model. The observed (expected) limit on the Higgs boson trilinear coupling modifier □□ is extracted to be [-1.5, 6.7] ([-2.4, 7.7]) at 95% confidence level. The constraints on □□ are obtained over an expected background hypothesis excluding □□ → □□ production. For the resonant production of a new hypothetical scalar particle □ (□ → □□ → □□-□□), limits on the cross section □□ → □ → □□ are presented for the narrow-width approximation as a function of □□ in the range 251 GeV ≤ □□ ≤ 1000 GeV. The observed (expected) limits on the cross section □□ → □ → □□ range from 610 fb to 47 fb (360–43 fb) over the considered mass range.

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Primordial black holes from a cosmic phase transition: The collapse of Fermi-balls

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We propose a novel primordial black hole (PBH) formation mechanism based on a first-order phase transition (FOPT). If a fermion species gains a huge mass in the true vacuum, the corresponding particles get trapped in the false vacuum as they do not have sufficient energy to penetrate the bubble wall. After the FOPT, the fermions are compressed into the false vacuum remnants to form non-topological solitons called Fermi-balls, and then collapse to PBHs due to the Yukawa attractive force. We derive the PBH mass and abundance, showing that for a $\mathcal{O}(\mathrm{GeV})$ FOPT the PBHs could be $\sim 10^{17}$ g and explain all of dark matter. If the FOPT happens at higher scale, PBHs are typically overproduced and extra dilution mechanism is necessary to satisfy current constraints.

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Search for doubly and singly charged Higgs bosons decaying into vector bosons in multi-lepton final states with the ATLAS detector using proton–proton collisions at $\sqrt{s}$ = 13 TeV

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A search for charged Higgs bosons decaying into $W^{\pm}W^{\pm}$ or $W^{\pm}Z$ bosons is performed,
involving experimental signatures with two leptons of the same charge, or three or four leptons with a variety of charge combinations, missing transverse momentum and jets.
A data sample of proton–proton collisions at a centre-of-mass energy of 13 TeV recorded with the ATLAS detector at the Large Hadron Collider between 2015 and 2018 is used.
The data correspond to a total integrated luminosity of 139 fb^{-1}.
The search is guided by a type-II seesaw model that extends the scalar sector of the Standard Model with a scalar triplet,
leading to a phenomenology that includes doubly and singly charged Higgs bosons.
Two scenarios are explored, corresponding to the pair production of doubly charged $H^{\pm\pm}$ bosons, or the associated production of a doubly charged $H^{\pm\pm}$ boson and a singly charged $H^{\pm}$ boson.
No significant deviations from the Standard Model predictions are observed.
$H^{\pm\pm}$ bosons are excluded at 95% confidence level up to 350 GeV and 230 GeV for the pair and associated production modes, respectively.

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New Physics bounded from above: 2HDM confronting strong 1st order electroweak phase transition

Author: mengchao Zhang[1]

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I will discuss the general difficulty in New Physics search, and how to put an upper limit on New Physics scale (which can be detected or excluded in the near future) via strong 1st order electroweak phase transition.

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电弱相变中引力波信号的精确计算

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The energy budget of electroweak first-order phase transition is essential for the gravitational wave spectra. Most of the previous studies are based on the bag model with same sound velocity in the symmetric and broken phase. We study the energy budget and the corresponding gravitational

wave spectra beyond the bag model, where the sound velocities could be different in the symmetric and broken phase. Taking the Higgs sextic effective model as a representative model, we calculate the sound velocities in different phase, the gravitational wave spectra and the signal-to-noise ratio for different combinations of phase transition parameters beyond the bag model. We compare these new results with the ones obtained from the bag model. The proper sound velocities and phase transition parameters at the appropriate temperature are important to obtain more precise predictions.

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Measurements of Higgs boson production using decays to two c-quarks with the ATLAS detector

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Testing the couplings of the Higgs boson to quarks is important to understand the origin of quark masses. The next most promising candidate is the decay to a pair of charm quark and antiquark.

The presentation will focus on the analysis of the associated production of the Higgs boson with a W or Z boson performed by the ATLAS Collaboration using data collected between 2015 and 2018, and will describe the analysis strategy employed to search for the H⟶cc signal. As a result, the best limit set on Higgs to charm quark Yukawa coupling modifier (κC) to date will be shown.

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Combined measurements of Higgs boson production and decay and constraints on the Higgs boson self-coupling from the combination of single-Higgs and double-Higgs production analyses performed with the ATLAS experiment

Author: Kunlin RAN[1]

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A combination of measurements of Higgs boson production cross sections and branching fractions is presented. The combination is based on the analyses of the Higgs boson decay modes H->yy, ZZ, *WW*, tautau, bb, mumu, and searches for decays into invisible final states. Up to 139 fb-1 of pp collision data collected at sqrt(s)=13 TeV with the ATLAS detector are used. Combined cross section measurements are presented for the ggF, VBF, WH, ZH and ttH. The global signal strength, defined as the measured Higgs boson signal yield normalized to its SM prediction, is determined to be mu=1.06+/-0.07. The combined measurement yields an observed (expected) significance for the WH of 6.3sigma (5.2sigma). Measurements in kinematic regions defined within the simplified template cross section framework are also shown. The results are interpreted in terms of modifiers applied to the Standard Model couplings of the Higgs boson to other particles. No significant deviations from SM predictions are observed.

Constraints on the Higgs boson self-coupling are set by combining the single Higgs boson analyses targeting the yy, ZZ, *WW*, tautau and bb decay channels and the double Higgs boson analyses in the bbbb, bbtautau and bbyy decay channels. The data used in these analyses correspond to an integrated luminosity of up to 79.8 fb-1 for single Higgs boson analyses and up to 36.1 fb-1 for the double Higgs boson analyses. With the assumption that new physics affects only the Higgs boson

self-coupling (lambda_HHH), values outside the interval [-2.3, 10.3] are excluded at 95% CL. Results with less stringent assumptions are also provided, introducing additional coupling modifiers for the Higgs boson interactions with the other SM particles.

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Higgs Alignment and Novel CP-Violating Observables in 2HDM

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Null results from searches for new physics at the Large Hadron Collider (LHC) enforce the belief that new particles must be much heavier than the weak scale. We undertake a systematic study of the interplay between Higgs alignment and CP-violation in complex two-Higgs-doublet models (C2HDMs), which enables us to construct a CP-violating scenario where new Higgs bosons are close to the weak scale after including stringent constraints from the electric dipole moment and measurements at the LHC. In addition, we propose a smoking-gun signal of CP-violation in the Higgs-to-Higgs decay, (h3 → h2h1 → 3h1), where h3,h2, and h1 are the heaviest, second heaviest and the SM-like neutral Higgs bosons, respectively. The mere presence of this decay channel is sufficient to establish CP-violation in C2HDMs. The final state with three 125 GeV Higgs bosons is distinct and provides a unique venue for new measurements at the LHC.

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Measurements of Higgs boson decaying into tau leptons using 139 ifb at the ATLAS experiment

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The most recent results for the cross-section measurements of the Higgs boson decaying into tau leptons at the ATLAS experiment will be presented. These results are setting the base for other searches in the Higgs boson sector in the tau final state aiming to look for physics beyond the Standard Model. The analysis is performed using the 139 ifb dataset recorded by the ATLAS experiment at LHC in the period 2015-2018. A description of the analysis strategy concerning the signal categorization as well as the background estimation will be given, followed by an overview and discussion of the main analysis results : the inclusive Higgs boson to tau cross-section, the cross-section measurement for each of the main Higgs boson production mode at the LHC and the measurements within the Simplified Template Cross Section (STXS).

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Next-to-leading order corrections for gg->ZH with top quark mass dependence

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Recently, we present for the first time a calculation of the complete next-to-leading order corrections to the $gg \to ZH$ process. We use the method of small mass expansion to tackle the most challenging two-loop virtual amplitude, in which the top quark mass dependence is retained throughout the calculations. We show that our method provides reliable numeric results in all kinematic regions, and present phenomenological predictions for the total and differential cross sections at the Large Hadron Collider and its future upgrades. Our results are necessary ingredients towards reducing the theoretical uncertainties of the $pp \to ZH$ cross sections down to the percent-level, and provide important theoretical inputs for future precision experimental collider programs. In this talk, I will start with a brief introduction to the small mass expansion and then show our new results for the ZH production at the LHC.

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Fiducial and differential cross-section measurements in the di-photon channel using full Run2 dataset at ATLAS

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Since the discovery of a scalar particle with mass at 125 GeV in the experiments ATLAS and CMS at LHC, different measurements based on its properties have been performed and the observations nicely correspond to the Higgs boson predicted by the Standard Model of particle physics. Among these measurements, the fiducial and differential cross-section play an important role in the test of the SM predictions as well as in the probe for BSM physics contributions exploring a variety of physics observables. Given that these measurements are performed in a specific region of the phase space (fiducial region), the model dependence is reduced. In this talk, the latest results on the differential and fiducial cross-section of the Higgs boson decay in the di-photon channel with full Run2 dataset (139 fb-1) collected with ATLAS experiment will be discussed.

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Search for Higgs boson pair production in the bbττ decay channel using 13 TeV pp collision data from the ATLAS detector

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A search for non-resonant and resonant Higgs boson pair production in bbττ final states is conducted using p-p collision data with an integrated luminosity of 139 fb−1 collected at s=√13 TeV by the ATLAS detector at the LHC. Events with at least one τ-lepton decaying hadronically are considered.

Multivariate analysis techniques are used to extract the signals. The talk will show an overview of the physics motivation, the analysis methodology as well as the preliminary results.

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Boosted technique for Higgs measurement and New Physics Searches

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Highly Lorentz-boosted scalar particles (Higgs or Radion) decaying to bb or WW->4q can be reconstructed as single large-radius jets, and identified using jet substructure and deep neural networks. The techniques can be exploited for both the SM Higgs measurement and New Physics Searches. Two recent applications at the CMS experiments will be covered in this talk, including, 1) a search for standard model Higgs bosons produced with transverse momentum (pT) greater than 450 GeV and decaying to bottom quark-antiquark pairs, and 2) a first search for resonances decaying into a radion and a W boson in proton-proton collision data, with the radion reconstructed through its decay into two W bosons. In the future, we expect to extend these techniques to boosted H->WW and Higgs pair studies.

Refs:
https://arxiv.org/abs/2006.13251
CMS-PAS-B2G-20-001
CMS-PAS-B2G-21-002

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Measuring Higgs Boson Self-couplings with 2→3 VBS Processes

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We study the measurement of Higgs boson self-couplings through 2 ⟶ 3 vector boson scattering (VBS) processes in the framework of Standard Model effective field theory (SMEFT) at both proton and lepton colliders. The SMEFT contribution to the amplitude of the 2 ⟶ 3 VBS processes, taking WLWL ⟶ WLWLh and WLWL ⟶ hhh as examples, exhibits enhancement with the energy A(BSM)/A(SM) ˜which indicates the sensitivity of these processes to the related dimension-six operators in SMEFT. Simulation of the full processes at both hadron and lepton colliders with a variety of collision energies are performed to estimate the allowed region on and . Especially we find that, with the help of exclusively choosing longitudinal polarizations in the final states and suitable cuts, WWh process is as important as the more widely studied triple Higgs production (hhh) in the measurement of Higgs self-couplings. Our analysis indicates that these processes can play important roles in the measurement of Higgs self-couplings at future 100 TeV pp colliders and muon colliders. However, their cross sections are generally tiny at low energy machines, which makes them much more challenging to explore.

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Effective picture of cosmic bubble expansion

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We derive an effective equation-of-motion for an expanding bubble wall in the thermal plasma with a general form of the thermal friction. The efficiency factor for gravitational waves productions from colliding bubble walls is obtained with a special interest for the strong first-order phase transition. Primary authors Prof. Rong-Gen Cai (ITP-CAS)， Shao-Jiang Wang

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Long-lived Particle(LLP) searching at the future collider

Author: Yulei Zhang[1]

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In contrast to the standard model particles, long-lived particles(LLPs) decay with a significant distance from the primary vertex. We present a novel LLPs search strategy based on machine learning (ML) and image recognition techniques utilizing detector information from future lepton colliders.

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Search for Resonant and Non-resonant VHH Production with ATLAS detector

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Probe BSM physics with the interaction between the Higgs boson and top quark

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Composite Higgs and Dark Matter

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Higgs potential and phase transition

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Precise theoretical predictions for Higgs processes

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Precise Higgs measurements at LHC

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Search for rare Higgs processes

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Introduction to the standard model and electro-weak symmetry breaking

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Extension of standard model, e.g. 2HDM

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Experimental Higgs physics, e.g. discovery, precise measurement, BSM Higgs searches

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The multilepton anomalies at the LHC and the prospect of new physics at the EW scale

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A study showed that the multilepton anomalies in the LHC data could be explained by adding two real scalar bosons to the SM. This study provides a more comprehensive set of LHC results of the multilepton production. We find that combining such results leads to substantial inconsistencies between the data and SM Monte Carlo predictions. These discrepancies appear in corners of the phase-space where different SM processes dominate, indicating that the potential miss modelling of a single SM process is unlikely to explain these excesses.

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Searches for light scalar and charged scalar

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Heavy neutral scalar searches

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BSM Higgs couplings

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Higgs bosons in new physics models

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