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Book of Abstracts
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Two-Loop $\mathcal{O}(\alpha_t^2)$ Trilinear Higgs Self-Couplings in the CP-Violating NMSSM

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In supersymmetric theories the Higgs boson masses are derived quantities where higher-order corrections have to be included in order to match the measured Higgs mass value at the precision of current experiments. Closely related through the Higgs potential are the Higgs self-interactions. In addition, the measurement of the trilinear Higgs self-coupling provides the first step towards the reconstruction of the Higgs potential and the experimental verification of the Higgs mechanism sui generis. In this talk, we report on most-recent precision predictions of the trilinear Higgs self-couplings in the CP-violating Next-to-Minimal Supersymmetric extension of the SM (NMSSM).

After a short technical introduction into higher-order corrections to supersymmetric Higgs-potentials the phenomenological impact of the recently obtained two-loop corrections onto the SM-like trilinear Higgs self-coupling as well as their correlation to the Higgs mass corrections are discussed. Finally, we discuss the inclusion of the loop-corrected effective trilinear Higgs self-coupling in gluon fusion into Higgs pairs and the estimate of the theoretical uncertainty due to missing higher-order corrections.

Measurements of observables sensitive to colour reconnection in $tt$ events with the ATLAS detector at 13 TeV

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Colour reconnection (CR) is a mechanism that describes the interactions that can occur between colour fields during the hadronisation transition. In the context of precise top-quark mass measurements, it plays a crucial role. The modelling of CR has become one of the dominant sources of systematic uncertainty in these measurements. Ongoing top-quark mass analyses use PYTHIA 8 MC event generator for parton showering and hadronisation. PYTHIA 8 comes with several alternative CR models which should be explored to estimate the CR modelling uncertainty. At the same time, the models should be confronted with LHC data to test their validity. Only models which are in agreement with data, in general, are suitable to define the corresponding modelling uncertainty. This analysis presents a measurement of charged-particle distributions sensitive to the different CR models in PYTHIA 8 in top-quark pair production. The measurement is based on data collected using the ATLAS detector at the LHC in proton-proton collisions at a centre-of-mass energy of 13 TeV with an integrated luminosity of 139 fb-1. Distributions of charged-particle multiplicity and of charged-particles scalar sum of transverse momentum are measured in the region outside of the selected jets and compared with predictions resulting from the different CR models.

Parallel Session / 4

Precise predictions for the trilinear Higgs coupling in arbitrary models

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The trilinear coupling of the 125-GeV Higgs boson, $\lambda_{hhh}$, is crucial quantity to study in the future. It controls the shape of the Higgs potential, away from the electroweak (EW) vacuum, and determines the strength of the EW phase transition. It can also deviate significantly from its SM prediction, even in scenarios where New Physics is hidden from direct observation (e.g. scenarios with alignment), due to non-decoupling effects in radiative corrections from Beyond-the-Standard-Model (BSM) scalars. Meanwhile, the experimental bounds on this coupling are already sufficiently strong to exclude significant parts of (otherwise unconstrained) parameter space of BSM theories. It is therefore crucial to have accurate predictions for $\lambda_{hhh}$ for the wide range of BSM models that are being investigated.

In this talk, I will present a new public tool, anyH3, providing predictions for the trilinear Higgs coupling, expressed in terms of the coupling modifier $\kappa_{\lambda}$, to full one-loop order within arbitrary renormalisable QFTs. This framework allows computing one-, two-, and three-point functions at one loop in an automated way, and offers additionally a high level of flexibility in the application of pre- or user-defined renormalisation conditions. I will review the main elements of the calculation and demonstrate features of the new computer program. Finally, I will discuss possible applications and extensions of this tool.

Parallel Session / 5

Measurement of inclusive production cross section of photons in association with $t\bar{t}$ in l+jets channel

Authors: Andreas Kirchhoff; Arnulf Quadt; Elizaveta Shabalina

None
The optimal way to measure the top-photon coupling and later interpret it within an EFT-framework would be an $e^+e^-$ collider with sufficient energy. As such a collider does not exist, another possibility is to look for $t\bar{t}$ pairs in association with a photon. Unfortunately, most of such photons will originate from the decay products of the top quarks and hence do not convey any information about the top-photon coupling. In contrast, photons produced in the production of the $t\bar{t}$ pair mostly originate from the top quark (beside a small contribution from ISR). The separation of photons originating from production and decay is tried for the first time in this ATLAS analysis. In this talk, the status of the currently ongoing inclusive cross section measurement of the $t\bar{t} + \gamma$ process in the $l+\text{jets}$ and dilepton channel will be presented. The talk will focus on two topics, the usage of deep neural networks to separate photons from the production stage from the background and the fit to extract the inclusive production cross section.

Parallel Session / 6

**New constraints on extended Higgs sectors from the trilinear Higgs coupling**

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The trilinear Higgs coupling $\lambda_{hhh}$ is crucial for determining the structure of the Higgs potential and for probing possible effects of physics beyond the Standard Model (SM). Focusing on the Two-Higgs-Doublet Model as a concrete example, we identify parameter regions in which $\lambda_{hhh}$ is significantly enhanced with respect to the SM. Taking into account all relevant corrections up to the two-loop level, we show that already current experimental bounds on $\lambda_{hhh}$ rule out significant parts of the parameter space that would otherwise be unconstrained. We illustrate the interpretation of the results on $\lambda_{hhh}$ for a benchmark scenario. Similar results are expected for wide classes of models with extended Higgs sectors.

Parallel Session / 8

**Measurement of the production cross-section of a W boson in association with ttbar**

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The top-quark pair production in association with a $W$ boson is an important background to processes like $t\bar{t}H$ or 4-tops production. Due to higher order electroweak corrections, the process is difficult to model. In consequence, a mismodelling of $t\bar{t}W$ surpassing $2\sigma$ has been observed in previous analyses. Thus, it is of high importance to increase our understanding of it.
This talk will give an overview of the measurement of the $t\bar{t}W$ cross-section in the multi-lepton channel, i.e. $2\ell SS$ and $3\ell$, using the full Run 2 dataset. In addition to a measurement in the inclusive phase space, the extraction of the cross-section in a fiducial phase space, as well as the measurement of the ratio $\sigma(t\bar{t}W^+)/\sigma(t\bar{t}W^-)$ will be discussed. The fit to extract the cross-section is performed simultaneously to a template fit estimating the main background contributions.

Parallel Session / 9

Measurement of Electron charge mis-identification rate for four top analysis

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The production of four top quarks is an extremely rare process which has not been observed yet. Also, its high sensitivity to the top Yukawa coupling and some beyond the standard model signatures make it a very interesting process to study. The decay channel where two of the top quarks decay into same sign leptons have a very low level of background contamination. One of the dominant backgrounds for this channel arises from the charge misidentification of the electrons. The mis-identification rate varies with the transverse momentum and the amount of detector material traversed by the electron. Hence a dedicated data driven approach is used to estimate this rate in two dimensional bins. In this talk, the method used for charge mis-identification rate extraction as well as estimation of the uncertainties will be presented.

Parallel Session / 10

First results from inclusive jet measurement with CMS Ultra-Legacy Run 2 data

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We present preliminary results of the measurement and QCD analysis of double-differential inclusive jet cross sections in proton-proton collisions by using the full Run II data collected by CMS experiment at LHC at a center of mass energy of 13 TeV. The higher accumulated luminosity of full Run II opens up new corners of the phase space. This permits further testing of the Standard Model (SM) and facilitates indirect searches for physics beyond the SM. Our study addresses the high transverse momentum region, where possible contributions of new physics, e.g. different models of 4-quark contact interactions, are most significant. Furthermore, the precision of the parton distribution functions can be significantly improved and the strong coupling constant can be extracted. In this talk, I will give an overview of the current status of the measurement.
Plenary / 11

EFTs at the LHC

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Plenary / 12

The CMS HGCAL upgrade

Parallel Session / 13

Precision predictions for ttbb at the LHC

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The greatest achievement of the LHC is the discovery of the Higgs boson in 2012. Testing the properties of this newly discovered particle represents a crucial task in the understanding of the fundamental laws of nature. Very important is to study how the Higgs boson couples to another exotic particle, the top quark. This can be done studying the process where the Higgs boson is produced in association with a top-quark pair ($t\bar{t}H$). This process represents only 1% of the total Higgs boson production rate. However, it allows to directly probe the top-quark Yukawa coupling. This study can be performed in various decay channels of the Higgs boson, for instance $t\bar{t}H(H\rightarrow b\bar{b})$. This is of course not a simple task, since these events are buried below a considerable amount of background events. Therefore, to correctly characterize this signature, one needs to properly describe the background. In my presentation I will investigate the $t\bar{t}b\bar{b}$ production at the LHC, which represents an irreducible background to $t\bar{t}H(H\rightarrow b\bar{b})$. This study has been performed in the dileptonic decay channel of the top quark with NLO QCD accuracy, both with full off-shell effects (namely without any approximation) and in the Narrow Width Approximation (where the heavy resonances are produced on-shell and then decayed). Then, I will show a comparison between these theoretical predictions and experimental results recently obtained by the ATLAS collaboration. I will also investigate the nature of the $b$-jets present in the process and provide a prescription to label them in order to better characterize the background.

Parallel Session / 14

Measurement of differential cross-sections of the $t\bar{t}\gamma$ production in semileptonic and dileptonic channel in proton-proton collisions at $\sqrt{s} = 13$ TeV with ATLAS detector

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The top quark being the heaviest fundamental particle in the Standard Model (SM) plays a very important role in the study of fundamental interactions. It has a very short lifetime and it decays
before it hadronizes, passing its properties to its decay products. Top quark pair production in
association with a photon ($t\bar{t}\gamma$) is a very important process for measuring the coupling between top
quark and photon. A precise measurement of this coupling is necessary for testing the SM and also
for probing any new physics effect at very high energy scale. Deviations from the SM coupling can
be a limit of new physics phenomena that can be interpreted in the context of effective field theory
approaches.

In this talk, measurement of $t\bar{t}\gamma$ differential cross-section using $139 \text{ fb}^{-1}$ of data collected by the
ATLAS detector in proton-proton collisions at $\sqrt{s} = 13 \text{ TeV}$ will be presented. This measurement
is done in the semileptonic and dileptonic decay channel of the $t\bar{t}$ pair.

Parallel Session / 15

Prospects for Constraints on $tZc$ Couplings Using Quantum Interference at Hadron Colliders

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Flavour-changing neutral currents in the top-quark sector are heavily suppressed in the Standard
Model. However, several theories beyond the Standard Model predict significant enhancements for
these transitions, motivating searches for them at current and future collider experiments.

In this talk, studies for the sensitivity to a left-handed $tZc$ coupling $g$ are presented. In contrast to
traditional searches that focus on leptonic $Z$ boson decays, an approach based on the interference
of diagrams containing the $t \rightarrow b\bar{c}$ transition in the decay of top-quark pairs is chosen. In the
Standard Model, this transition occurs via the CKM-suppressed $W^+ \rightarrow b\bar{c}$ decay, while the $Z \rightarrow b\bar{b}$
decay contributes in the case of a non-vanishing coupling $g$.

The signal topology comprises four $b$-tagged jets, one lepton, and missing transverse energy. The
expected 95\% CLs upper limit on the coupling $g$ is obtained using the output distributions of a
parametrised multiclass neural network. The interference-based approach is projected to be slightly
less sensitive than the traditional approach at the HL-LHC, while the limits become comparable for
an FCC-hh scenario, highlighting the advantage of the presented method when probing increasingly
smaller couplings with large statistical power.

Plenary / 16

Welcome from DESY

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Plenary / 17

The Alliance ”Physics at the Terascale”: Future prospects

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Plenary / 18

**The Belle II experiment: Status and prospects**

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Plenary / 19

**News from the flavour sector**

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Plenary / 20

**Opportunities for gravitational wave experiments at DESY**

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Parallel Session / 21

**Refining fast simulation using machine learning**

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At the CMS experiment, a growing reliance on the fast Monte Carlo application (FastSim) will accompany the high luminosity and detector granularity expected in Phase 2. The FastSim chain is roughly 10 times faster than the application based on the GEANT4 detector simulation and full reconstruction referred to as FullSim. However, this advantage comes at the price of decreased accuracy in some of the final analysis observables. In this contribution, a machine learning-based technique to refine those observables is presented. We employ a regression neural network trained with a sophisticated combination of multiple loss functions to provide post-hoc corrections to samples produced by the FastSim chain. The results show considerably improved agreement with the FullSim output and an improvement in correlations among output observables and external parameters. This technique is a promising replacement for existing correction factors, providing higher accuracy and thus contributing to the wider usage of FastSim.

Parallel Session / 22

**Development of machine-learning based topological algorithms for the CMS L1 trigger**

*Author:* Finn Jonathan Labe\(^1\)

*Co-authors:* Artur Lobanov\(^1\); Gregor Kasieczka\(^2\); Johannes Haller\(^3\); Matthias Schroeder\(^1\)
At the CMS experiment, a two-layer trigger system is used to decide which collision events to store for later analysis. Due to the large number of low energy collisions at the LHC, currently used triggers often rely on momentum thresholds, only triggering on events with at least one highly energetic object. In searches for certain signatures, this leads to potentially relevant events being discarded in the trigger system. Novel techniques, utilizing machine learning inside the first hardware layer of the trigger, are studied to recover this phase space. Instead of individual objects, these triggers rely on the full event topology to trigger on previously inaccessible events.

Parallel Session / 23

Generating Calorimeter Showers as Point Clouds

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In particle physics, precise simulations are necessary to enable scientific progress. However, accurate simulations of the interaction processes in calorimeters are complex and computationally very expensive, demanding a large fraction of the available computing resources in particle physics at present. Various generative models have been proposed to reduce this computational cost. Usually, these models interpret calorimeter showers as 3D images in which each active cell of the detector is represented as a voxel. This approach becomes difficult for high-granularity calorimeters due to the larger sparsity of the data. In this study, we use this sparseness to our advantage and interpret the calorimeter showers as point clouds. More precisely, we consider each hit as part of a hit distribution depending on a global latent calorimeter shower distribution. A first model to learn calorimeter showers as point clouds is presented. The model is evaluated on a high granular calorimeter dataset.

Parallel Session / 24

Increased CP sensitivity with a neural network constructed observable in an effective Higgs-gluon coupling

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The Higgs sector is a prominent candidate for providing additional sources of CP violation beyond the SM. The cleanest way to constrain the amount of CP violation is by measuring CP-odd observables. However, most of the current analyses do not take into account the full kinematics of the processes. We present an approach in which a CP-odd observable can be constructed from the output of a neural network that has been trained on recognizing the CP structure of BSM events. Focusing on the CP structure of the Higgs-gluon coupling, we compare the sensitivity of this approach to a more traditional CP-odd observable.
Parallel Session / 25

Search for new particles decaying to top quark pairs at CMS

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A search for new particles decaying to top quark pairs is presented. The analysis uses pp-collision data with a center-of-mass energy of 13 TeV, collected with the CMS experiment during Run-2 of the LHC. The data correspond to an integrated luminosity of $138 \text{ fb}^{-1}$. The search is performed in final states with one lepton, missing transverse energy and jets, and exploits novel top-tagging techniques to identify the hadronic decay of top quarks. A multi-class neural network has been developed to categorise the events in the main backgrounds from known standard model processes. Expected exclusion limits are set for different benchmark models, targeting both resonant and non-resonant signatures.

Parallel Session / 26

First measurement of the top quark pair production cross section at 13.6 TeV

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The first measurement of the top quark pair production cross section in proton-proton collisions at $\sqrt{s} = 13.6$ TeV is presented. A novel measurement technique, based on a likelihood fit to events with one or two charged leptons, is used to analyze data recorded with the CMS detector at the CERN LHC corresponding to an integrated luminosity of $1.20 \text{ fb}^{-1}$. The measured cross section is $887^{+68}_{-67} \text{ pb}$, in agreement with the standard model prediction.

Parallel Session / 27

Efficient search for new physics using Active Learning in the ATLAS Experiment using RECAST

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Searches for new physics and their reinterpretations constrain the parameter space of models with exclusion limits in typically only few dimensions. However, the relevant theory parameter space often extends into higher dimensions. Limited computing resources for signal process simulations impede the coverage of the full parameter space. We present an Active Learning approach to address this limitation, using the RECAST reinterpretation framework. Compared to the usual grid sampling, it reduces the number of parameter space points for which exclusion limits need to be determined. Consequentially, it allows to extend interpretations of searches to higher dimensional parameter spaces and therefore to raise their value, e.g. via the identification of barely excluded subspaces which motivate dedicated new searches. The
procedure is demonstrated by reinterpreting a Dark Matter search performed by the ATLAS experiment, extending its interpretation from a 2 to a 4-dimensional parameter space while keeping the computational effort at a low level.

Parallel Session / 28

Search for charged Higgs bosons in $H^+ \rightarrow Wh$ decays with the ATLAS detector

Authors: Dominik Duda; Hubert Kroha; Simon Grewe; Sandra Kortner

Various theories predicting an extended Higgs sector predict also the existence of at least one set of charged Higgs bosons. The main production mode of these new particles depends on their mass. For charged Higgs boson masses larger than the sum of the top and the bottom quark mass, the dominant production mode is expected to be in association with a top quark and a bottom quark ($tbH^+$).

In the alignment limit of the Two-Higgs-Doublet Model (2HDM), heavy charged Higgs bosons with $m(H^+) > m(t) + m(b)$ decay almost exclusively via $H^+ \rightarrow tb$. However, in other models such as the Next-to-Two-Higgs-Doublet Model (N2HDM), the Three-Higgs-Doublet model (3HDM) or in Higgs triplet models (e.g. Georgi-Machacek model), significant branching ratios for $H^+ \rightarrow W^+h$ are possible. The latter decay mode has so far been covered neither by ATLAS nor CMS.

This talk will present a search for charged Higgs bosons in $H^+ \rightarrow W^+h$ decays with the ATLAS detector on the full Run-2 dataset. The analysis targets final states with the resolved topology containing five or more jets, one charged lepton and missing transverse momentum. The reconstruction of the charged Higgs boson decay is performed using boosted decision trees (BDTs). Furthermore the definition of signal and control regions is based on the output of the BDTs. Limits on $\sigma(pp \rightarrow tbH^+) \times BR(H^+ \rightarrow Wh)$ are obtained by a maximum likelihood fit to the reconstructed $H^+$ mass spectrum.

Parallel Session / 29

CMS tracker alignment with early Run 3 data

Author: Sandra Consuegra Rodriguez

The strategies for and the performance of the CMS tracker alignment during the ongoing LHC Run 3 data-taking period are described. The data-driven methods used to derive the alignment parameters for data reprocessing and the set of validations that monitor the physics performance after the update of the tracker alignment constants are reviewed.
Parallel Session / 30

**ttbb modelling for ttH analyses at the LHC**

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The search for Higgs boson production in association with a top quark pair (ttH) has been performed in the H to bb decay channel at the LHC. These searches are limited by the modelling uncertainties of the main background: ttbb. The aim is to compare the modelling of important backgrounds to ttH measurements in the ttH(H->bb) decay channel and the treatment of the associated theory uncertainties for a combination of the full Run-2 ttH results from ATLAS and CMS. This paves the way for a discussion between experiments and theorists to define such modelling uncertainties in view of future combinations of the experimental results. As a first step, modelling and theory uncertainties as used in ATLAS an CMS are compared in the relevant analysis regions. This talk focuses on the Monte Carlo generator comparisons of the ttbb processes at particle level and highlights the results documented in the LHC Higgs Working Group Public Note LHCHWG-2022-003.

Parallel Session / 31

**Study of the Higgs boson production via Vector Boson Fusion in the H->bb decay channel**

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We present a measurement of the signal strength of the Higgs boson decaying to a pair of bottom quarks and produced via Vector Boson Fusion (VBF). The study is performed using 91 fb of pp collision data collected by the CMS experiment at a centre-of-mass energy of 13 TeV. The measurement is performed for events with at least four energetic jets: two b-jets originating from the Higgs boson decay and two forward "VBF-tagged" jets. A Boosted Decision Tree (BDT) classification is used to separate the signal from the major background processes: QCD multijet production and Z+jets events. The signal is extracted from simultaneous fit applied in multiple event categories with varying signal-to-background ratio to the distribution of the invariant mass of two identified b-jets. The VBF signal is observed with a significance of 2.4 standard deviations relative to the background prediction, while the expected significance is 2.7 standard deviations.

Parallel Session / 32

**Anomaly detection for the level 1 trigger system of the CMS experiment**

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There exist strong hints for the existence of physics beyond the standard model (BSM). At the CMS experiment, the first event selection step is the Level 1 (L1) trigger system, which decides whether an event is stored for further analysis. Assuming that BSM events differ from standard model (SM) events, a trigger decision could then utilize this difference to detect anomalous event properties instead of being fully based on model specific criteria.

This talk discusses such an anomaly detection trigger based on neural networks. An autoencoder (AE) network is trained to reproduce typical collision events. The quality of the reproduction is worse when the AE is used with BSM events with anomalous properties. This decrease in reproduction quality can then be used as a basis for the trigger decision. Since the L1 trigger has a very limited time for the decision, the AE needs to be deployed on dedicated hardware in the form of field programmable gate arrays which presents additional challenges.

Parallel Session / 33

Heavy Neutrinos at Future Lepton Colliders

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Neutrinos are probably the most mysterious particles of the Standard Model. The mass hierarchy and oscillations, as well as the nature of their antiparticles, are currently being studied in experiments around the world. Moreover, in many models of New Physics, baryon asymmetry or dark matter density in the universe are explained by introducing new species of neutrinos. Heavy neutrinos of the Dirac or Majorana nature with masses above the EW scale could be produced at future lepton colliders.

We studied the possibility of observing production and decays of heavy neutrinos into 2j+1 final state at future Higgs factories ILC and CLIC, as well as at Muon Collider. The analysis is based on the WHIZARD event generation and fast simulation of the detector response with DELPHES. Dirac and Majorana neutrinos with masses up to 10 TeV are considered. Estimated limits on the production cross sections and on the heavy-light neutrino mixing parameter are compared with the current limits coming from the LHC running at 13 TeV and the expected limits from HL-LHC and future hadron colliders. Obtained results are stricter than other limit estimates published so far.

Parallel Session / 34

On the contribution of the electromagnetic dipole operator to the $\bar{B}_s \rightarrow \mu^+\mu^-$ decay amplitude

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We report on the construction of a factorization theorem that allows to systematically include QCD corrections to the contribution of the electromagnetic dipole operator $\mathcal{O}_7$ to the $\bar{B}_s \rightarrow \mu^+\mu^-$ decay amplitude. We elaborate on how the occurring endpoint divergences appearing in individual momentum regions cancel, and show how the resulting rapidity logarithms can be isolated by suitable subtractions applied to the corresponding bare factorization theorem. This allows to
include in a straightforward manner the QCD corrections arising from the renormalization-group running of the hard matching coefficient, the hard-collinear scattering kernel, and the $B_s$-meson distribution amplitude. We estimate the effect numerically using a recently advocated parameterization of the $B_s$-meson light-cone distribution amplitude.

Parallel Session / 35

Prospects for strong coupling measurement at hadron colliders using soft-drop jet mass

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We compute the soft-drop jet-mass distribution from $pp$ collisions to NNLL accuracy while including nonperturbative corrections through a field-theory based formalism. Using these calculations, we assess the theoretical uncertainties on an $\alpha_s$ precision measurement due to higher order perturbative effects, nonperturbative corrections, and PDF uncertainty. We identify which soft-drop parameters are well-suited for measuring $\alpha_s$, and find that higher-logarithmic resummation has a qualitatively important effect on the shape of the jet-mass distribution. We find that quark jets and gluon jets have similar sensitivity to $\alpha_s$, and emphasize that experimentally distinguishing quark and gluon jets is not required for an $\alpha_s$ measurement. We conclude that measuring $\alpha_s$ to the 10% level is feasible now, and with improvements in theory a 5% level measurement is possible. Getting down to the 1% level to be competitive with other state-of-the-art measurements will be challenging.

Parallel Session / 36

Top quark charge asymmetry in highly boosted events in the single lepton channel at 13 TeV

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The measurement is performed on highly boosted top quark pair events resulting in non isolated leptons and overlapping jets. Jet substructure variables are used to identify the boosted top quark and the W boson. The top quark charge asymmetry is measured for events with $t\bar{t}$ invariant mass larger than 750 GeV. The measurement is found to be in good agreement with the standard model prediction at next-to-next-to-leading order in perturbation theory with next-to-leading order electroweak corrections.

Parallel Session / 37

Probing the minimal dark abelian gauge sector at the intensity frontier

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Dark photons originated from new hidden abelian symmetries are one of the best motivated extensions of the Standard Model. However, the simple addition of a massive vector in the low energy theory might cause problems at high energies, meaning that there must be other new physics states charged under this new hidden symmetry. One way out is to directly UV complete the model by adding a dark Higgs mechanism. In this talk, I will present how the usual dark photon and dark Higgs phenomenology can be modified in this context by exploring meson decays at the KOTO, LHCb and BelleII experiments, and also by studying the impacts on the Higgs invisible width.

Parallel Session / 38

Probing the Weak Mixing Angle at high energies at the LHC

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The electroweak mixing angle is a fundamental parameter of the theory of electroweak interactions. Its value has been measured precisely at the $Z$-pole at colliders. In this contribution, we propose to exploit measurements of Neutral-Current Drell-Yan production at the Large Hadron Collider at large invariant dilepton masses to determine the energy scale dependence (running) of the electroweak mixing angle in the $\overline{\text{MS}}$ renormalisation scheme, $\sin^2 \theta_{W,\ell}^{\overline{\text{MS}}}(\mu)$. Such a measurement can be used to confirm the Standard Model predictions for the $\overline{\text{MS}}$ running at TeV scales, and to set model-independent constraints on new states with electroweak quantum numbers. To this end, we make use of a dedicated implementation of $\sin^2 \theta_{W,\ell}^{\overline{\text{MS}}}(\mu)$ in the POWHEG-BOX-V2 Monte Carlo event generator, which we use to explore the potential of future analyses using the data of the LHC Run 3 and High-Luminosity.

Parallel Session / 39

Multi-emission kernels for parton branching algorithms

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We will discuss a novel framework for addressing QCD factorization in the emission of multiple soft or collinear partons. The purpose of this discussion is to allow for a more precise description of hadron collider data and to better handle theoretical uncertainties from parton showers. We have developed a power counting algorithm in emission amplitudes with the goal of parameterizing the accuracy of different types of parton showers. An example are inaccuracies introduced by iterating single emission amplitudes vs. the use of a multi-emission kernel. Eventually, this approach should pave the way for higher orders in QCD in parton showers.
The photon energy spectrum in $\mathbf{B}\mathbf{X}_s\gamma$ at $\mathcal{N}^3\LL'$

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The smallest element of the CKM matrix, $|V_{ub}|$, can be extracted from measurements of semileptonic $B$ meson decay $B \rightarrow X_u l \nu$. However, the experimental signal of this process is obscured by large backgrounds, which are absent only at the edge of the phasespace. Resummation of perturbative series is essential in this kinematic region. Furthermore, this region is sensitive to Fermi motion of the $b$-quark inside the $B$-meson. Factorization theorems derived in Soft-Collinear Effective Theory are used to separate dynamics at different energy scales. The factorization also isolates nonperturbative effects in a so-called shape function. The shape function cannot be calculated perturbatively, but it can be measured in $B \rightarrow X_s\gamma$ decay.

I will present our preliminary predictions of $B \rightarrow X_s\gamma$ spectrum at $\mathcal{N}^3\LL'+\mathcal{N}^3\text{LO}$. We parameterize the few unknown 3-loop perturbative ingredients, - a hard function coefficient and nonsingular contributions - using nuisance parameters. The variation of these nuisance parameters provides a robust estimate of the uncertainty that arises from our ignorance of these 3-loop terms.

In order to arrive at stable predictions it is essential to use a short-distance scheme for the $b$-quark mass. It is well-known that the pole mass scheme suffers from a renormalon problem, which leads to very poor convergence. We demonstrate that predictions in 1S mass scheme, which has been used for this process in the past, start to break down at $\mathcal{N}^3\text{LO}$ due to a mismatch between the 1S scale and the soft scale of this process. I will show that the MSR mass scheme yields much more stable results.

**QCD Generative Model Without Machine Learning**

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The Rebalance and Smear technique for the modeling of QCD backgrounds to searches for dark matter at the LHC is presented as a publicly available toolkit. Bayesian inference is carried out on real data events to estimate a latent space of the true jet energy values within each event. The latent space is sampled multiple times per event according to a known PDF of the detector response to the jet energy, and the resulting collection represents a high-statistics proxy for the true QCD background. This method, previously carried out at CMS and ATLAS for background estimation, can also be employed in the training of multivariate classifiers to optimally reject QCD background, potentially extending the sensitivity of searches to BSM scenarios with compressed mass spectra. An example future search probing pure Higgsino dark matter in gluino and squark simplified models, is a good candidate for this method in Run 3.
Search for pair-produced scalar and vector leptoquarks decaying into third-generation quarks and first- or second-generation leptons in $pp$ collisions with the ATLAS detector

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Final results of a search for pair-produced scalar and vector leptoquarks (LQs) in single-lepton final states are presented. The LQs are assumed to couple to third-generation quarks and first- or second-generation leptons. Such LQs with flavour-off-diagonal couplings arise for example in theories aiming for explanations of anomalies observed in $b\to s\ell\ell$ and $b\to c\ell\nu$ transitions.

In the search, the full Run-2 dataset collected with the ATLAS detector in proton-proton collisions at centre-of-mass energies of 13 TeV is used, corresponding to an integrated luminosity of 139 fb$^{-1}$. Neural networks are employed in order to efficiently distinguish signal contributions from background processes. In the absence of significant deviations from the Standard Model prediction, exclusion limits on eight LQ models are derived.

Parallel Session / 43

A bridge to new physics – explaining g-2 and connecting it to other flavour anomalies

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In this talk I will go over the study of a new class of SM extensions which can contribute towards the anomalous magnetic moment of the muon with chiral enhancement. We will focus on a particular 3-field extension which explains g-2 at one-loop but can also account for tree-level solutions of the neutral B-anomalies and the Cabibbo angle anomaly.

Parallel Session / 45

Improved Constraints on Effective Top Quark Interactions using Edge Convolution Networks

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Reinterpreting the LHC results as bounds on the Wilson Coefficients (WCs) of the Standard Model Effective Field Theory (SMEFT) allows studying new-physics effects in a model-independent way with minimal assumptions. However, the large number of effective interactions along with theoretical and experimental uncertainties result in poor constraints on WCs that motivate the use of alternative techniques with more comprehensive extraction of information from data. In this presentation, I will talk about constructing physics-inspired graphs from the final states of $pp \to t\bar{t}$
production with semi-leptonic top decays, and using Edge Convolution Neural Networks in order to condense the multidimensional phase space information. When using the output of the Neural Network to identify a signal region such that the SM contribution is minimised, the approach yields improvements on the bounds of WCs, compared to analyses on inclusive collision data employing differential distributions to measure deviations from the SM.

Parallel Session / 46

The shift-invariant orders of an ALP

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Usually, effective field theories (EFTs) for axion-like particles (ALPs) are built assuming a shift symmetry for the ALP due to the global U(1) Peccei-Quinn (PQ) symmetry that is at the heart of the axion mechanism. However, it is generally believed that global symmetries, in particular axion shift symmetries, can only be approximate. Therefore, it is important to include shift-breaking interactions in the EFT description and find a clear way to implement the different power countings of the shift-conserving and shift-breaking sectors. Focusing on the flavorful effective Yukawa couplings to Standard Model fermions, I will present Jarlskog-like flavor invariants which act as order parameters for shift symmetry breaking of the axion. In this description, shift-breaking couplings are characterized in an explicit and flavor-invariant way and it is straightforward to give different power countings to the shift-conserving and shift-breaking sectors. I will discuss properties of the invariants like their evolution under RG flow and their connection to CP violation. Finally, I will discuss examples of matching UV theories to the invariants and how they can be used to identify shift-breaking contributions in observables.