

# **QCD@LHC2017**

Sunday, August 27, 2017 - Friday, September 1, 2017

Other Institutes

## **Book of Abstracts**



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**Hard QCD and EW / 2****Multidimensional observables and Mustraal frame****Author:** Zbigniew Andrzej Was<sup>1</sup>**Co-author:** Elzbieta Richter-Was<sup>2</sup><sup>1</sup> *Polish Academy of Sciences (PL)*<sup>2</sup> *Jagiellonian University (PL)***Corresponding Authors:** elzbieta.richter-was@cern.ch, z.was@cern.ch

To define precision observables in a way which is most suitable for interpretation it is convenient to separate electroweak and QCD effects for pp collision processes@LHC. We argue, that for that purpose, choice of orientation of coordinates (in the rest frame of lepton pair) for Drell Yan processes can be beneficial to reduce entanglement of QCD and electroweak effects. Numerical results for single W and Z production processes will be provided. The event re-weighting tool, TauSpinner, for electroweak and New Physice effects will be presented.

**Top, heavy quarks and searches / 4****Top quark production cross-section measurements****Author:** Yoram Rozen<sup>1</sup><sup>1</sup> *Technion (IL)***Corresponding Authors:** shota.suzuki@cern.ch, rozen.yoram@gmail.com

Measurements of the inclusive and differential cross-sections for top-quark pair and single top production cross sections in proton-proton collisions with the ATLAS detector at the Large Hadron Collider are presented at center-of-mass energies of 8 TeV and 13 TeV. The inclusive measurements reach high precision and are compared to the best available theoretical calculations. These measurements, including results using boosted tops, probe our understanding of top-pair production in the TeV regime. The results are compared to Monte Carlo generators implementing LO and NLO matrix elements matched with parton showers and NLO QCD calculations.

For the t-channel single top measurement, the single top-quark and anti-top-quark total production cross-sections, their ratio, as well as differential cross sections are also presented. A measurement of the production cross-section of a single top quark in association with a W boson, the second largest single-top production mode, is also presented. Finally, measurements of the properties of the Wtb vertex allow to set limits on anomalous couplings. All measurements are compared to state-of-the-art theoretical calculations.

**Hard QCD and EW / 6****Study of Multiboson Production with the ATLAS detector.****Author:** Yoram Rozen<sup>1</sup><sup>1</sup> *Technion (IL)***Corresponding Authors:** takashi.kubota@cern.ch, rozen.yoram@gmail.com

Measurements of the cross sections of the production of pairs of electroweak gauge bosons at the LHC constitute stringent tests of the electroweak sector of the Standard Model and provide a model-independent means to search for new physics at the TeV scale. The ATLAS collaboration has performed detailed measurements of integrated and differential cross sections of the production of heavy di-boson pairs, such as WW, WZ and ZZ, in the fully-leptonic and partially in the semi-leptonic final states at centre-of-mass energies of 8 and 13 TeV.

Moreover, searches for the production of three W bosons or of a W boson and a photon together with a Z or W boson at a center of mass energy of 8 TeV will be presented. These studies are closely connected to the electroweak production of a heavy boson and a photon together with two jets. Evidence has been found for the exclusive production of W boson pairs, which will be presented in this talk.

Hard QCD and EW / 7

## Measurements of Vector boson fusion with the ATLAS detector

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The most recent results on the production of single W and Z bosons with two jets at high invariant mass at centre-of-mass energies of 7, 8 and 13 TeV are presented. Integrated and differential cross sections are measured in many different phase space regions with varying degree of sensitivity to the electroweak production in vector boson fusion. The cross section for the electroweak W boson production has been extracted for both integrated and for the first time differential distributions. The results are compared to state-of-the-art theory predictions and are used to constrain anomalous gauge couplings.

Hard QCD and EW / 8

## Precision measurements of electroweak observables with the ATLAS Detector

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Measurements of the Drell-Yan production of W and Z/gammaposons at the LHC provide a benchmark of our understanding of perturbative QCD and probe the proton structure in a unique way. The ATLAS collaboration measured the di-lepton mass range up to the TeV scale as well as the triple differential cross-section measurement as a function of  $M_{ll}$ , dilepton rapidity and  $\cos\theta$  defined in the Collins-Soper frame. This measurement provides sensitivity to the PDFs and the weak mixing angle. The latest results of the ATLAS collaboration will be presented.

A second important observable in the electroweak sector is the W boson mass in order to test the overall consistency of the Standard Model. Since the discovery of a Higgs Boson, the the W boson mass is predicted to 7 MeV precision, while the world average of all measurements is 15 MeV, making the improved measurement an important goal. Large samples of leptonic decays of W and Z bosons were collected with efficient single lepton triggers in the 7 TeV data set corresponding to an integrated luminosity of 4.6/fb. With these samples the detector and physics modelling has been



studied in great detail and enabled a W boson mass measurement with a precision of 19 MeV, which will be presented in this talk.

Hard QCD and EW / 9

## High Precision Measurement of the differential W and Z boson cross-sections

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Measurements of the Drell-Yan production of W and Z/gammaposons at the LHC provide a benchmark of our understanding of perturbative QCD and probe the proton structure in a unique way. The ATLAS collaboration has performed new high precision measurements at center-of-mass energies of 7. The measurements are performed for W+, W- and Z/gamma bosons integrated and as a function of the boson or lepton rapidity and the Z/gamma\* mass. Unprecedented precision is reached and strong constraints on Parton Distribution functions, in particular the strange density are found.

Z cross sections are also measured at a center-of-mass energies of 8TeV and 13TeV, and cross-section ratios to the top-quark pair production have been derived. This ratio measurement leads to a cancellation of several systematic effects and allows therefore for a high precision comparison to the theory predictions.

Hard QCD and EW / 10

## Measurements of the production of jets in association with a W or Z boson with the ATLAS detector

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The production of jets in association with vector bosons is an important process to study QCD in a multi-scale environment. The ATLAS collaboration has performed measurements of vector boson+jets cross sections, differential in several kinematic variables, in proton-proton collision data taken at center-of-mass energies of 8TeV and 13TeV. The measurements are compared to state-of-the-art theory predictions and can be used to constrain the proton structure.

We have also studied the jet production rates at different resolution scales. In particular, we present a measurement of the splitting scales in the kt jet-clustering algorithm for final states containing a Z-boson candidate at a centre-of-mass energy of 8 TeV. The data are corrected for detector effects and are compared to state-of-the-art Monte Carlo predictions.

Hard QCD and EW / 11

## Study of photon production also in association with jets with the ATLAS detector

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The production of prompt isolated photons at hadron colliders provides a stringent test of perturbative QCD and can be used to probe the gluon density function of the proton.

The ATLAS collaboration has performed precise measurements of the inclusive production of isolated prompt photons at a center-of-mass energy of 13 TeV, differential in both rapidity and the photon transverse momentum. In addition, the integrated and differential cross sections for isolated photon pair production and for triple-photon production at 8 TeV have been measured. The results are compared with state-of-the-art theory predictions at NLO in QCD and with predictions of several MC generators.

The production of prompt photons in association with jets in proton–proton collisions provides a further testing ground for perturbative QCD (pQCD) with a hard colourless probe less affected by hadronisation effects than jet production alone. We present cross-section measurements performed at cms energies of 8TeV and 13TeV, using final states with hadronic jets in addition to an isolated photon, differential in several kinematic variables describing the photon+jet production dynamic. The results are compared to recent theoretical predictions. We have also measured the cross section for the production of heavy-flavoured jets in association with a photon and studied the impact on the proton structure.

**Hard QCD and EW / 12**

## Measurement of jet production with the ATLAS detector and extraction of the strong coupling constant

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The production of jets at hadron colliders provides a stringent test of perturbative QCD at the highest energies. The process can also be used to probe the gluon density function of the proton. Specific topologies can be used to extract the strong coupling constant.

The ATLAS collaboration has recently measured the inclusive jet production cross section in data collected at a center-of-mass energy of 8TeV and 13TeV. The measurements have been performed differentially in jet rapidity and transverse momentum. The collaboration also presents a first measurement of the di-jet cross section at a center-of-mass energy of 13TeV as a function of the di-jet mass and rapidity. The results have been compared with state-of-the-art theory predictions at NLO in pQCD, interfaced with different parton distribution functions and can be used to constrain the proton structure.

We also present new measurements of transverse energy-energy correlations (TEEC) and their associated asymmetries (ATEEC) in multi-jet events at a center-of-mass energy of 8TeV. The data is unfolded to the particle level and compared to the expectations from parton shower Monte Carlo programs as well as from next-to-leading order perturbative QCD calculations. The same data is used to measure the combined rapidity and pT dependence of dijet azimuthal decorrelations. Both measurements are used to extract the strong coupling constant and test the renormalization group equations.

**Parton Distribution Functions and Soft QCD / 13**

## Measurements of low energy observables in proton-proton collisions with the ATLAS Detector

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Low energy phenomena have been studied in detail at the LHC, providing important input for improving models of non-perturbative QCD effects. The ATLAS collaboration has performed several new measurements in this sector:

We present charged-particle distributions sensitive to the underlying event, measured by the ATLAS detector in proton-proton collisions at a centre-of-mass energy of 13 TeV. The results are corrected for detector effects and compared to predictions from various Monte Carlo generators.

ATLAS has also studied the correlated hadron production. In particular, an analysis of the momentum difference between charged hadrons in high-energy proton-proton collisions is performed and the results are compared to the predictions of a helical QCD string fragmenting model.

We also present studies of the production of neutral strange particles inside and outside light and heavy-flavoured jets. The results are compared with various Monte-Carlo models.

New results in forward physics are expected to be available soon. We close this presentation with the measurement of the exclusive  $\gamma\gamma \rightarrow \mu^+\mu^-$  production in proton-proton collisions at a center-of-mass energy of 13 TeV.

**Hard QCD and EW / 14**

## Improvements of the sector-improved residue subtraction scheme

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Decreasing errors in experimental data obtained from colliders like the LHC makes it necessary to invoke higher and higher orders in theory predictions. A crucial part of the NNLO QCD predictions is the handling of the double real radiation phase-space and the cancellation of IR divergences with other contributions. I present a new phase-space parameterization for the sector-improved residue subtraction scheme as well as a new method for the evaluation of the corrections needed to employ the four-dimensional 't Hooft - Veltman scheme. Furthermore novel applications of the subtraction scheme are discussed.

**Top, heavy quarks and searches / 15**

## The top-quark mass: uncertainties due to bottom-quark fragmentation

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I will discuss the theoretical uncertainties on the top-quark mass determination, due to bottom-quark fragmentation in top decays. In particular, the fragmentation parameters in both HERWIG and PYTHIA, the two main parton shower generators, will be taken into account and their impact on several observables, relevant for the top-mass extraction, will be investigated. Furthermore, I will also comment on the role played by fragmentation uncertainties on the identification of the measured mass with the top-quark pole mass.

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## A Study of the Top Mass Determination Using New NLO+PS generators

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We estimate the top-quark mass extraction uncertainty due to Monte Carlo modeling of top-pair production and its leptonic decay. Using three different NLO+PS generators based on the POWHEG method implementing an increasingly precise treatment of  $t\bar{t}$  production and decay, including hvq and  $b\bar{b}4L$ , and two different PS implementations we obtain predictions for various kinematic distributions suitable for extraction of the top mass proposed in the literature. Assuming that one of the generators reproduces the data fully, we estimate the shift in the extracted top mass using the other generators. We find that the mass shifts are comparable if not larger than the current experimental uncertainty on the top mass extraction.

**Resummation and Monte Carlo generators / 18**

## What is a parton shower?

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We present a formulation for a parton shower at an arbitrary order of perturbation theory, with the aim of indicating how a parton shower can be understood as a systematically improvable approximation, similarly to ordinary perturbative calculations of cross sections. The formalism requires input functions that represent the soft and collinear singularities of QCD at the requisite perturbative order. The structure of the shower is unified with the structure of subtraction terms that remove soft and collinear singularities from a perturbative hard scattering cross section. The formalism is exact in the quantum color and spin variables for the partons.

**Top, heavy quarks and searches / 19**

## Associated production of a top pair and a Higgs/W/Z boson at the LHC to NNLL accuracy

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I am going to present some recent results on the resummation of soft gluon emission corrections to the production of a top-antitop pair in association with a Higgs/W/Z boson at the Large Hadron Collider.

First I will introduce and describe the derivation of the soft-gluon resummation formula for these processes. Based on this formula, we developed a dedicated parton-level Monte Carlo program. This tool has been used to calculate the total cross section along with differential distributions in order to study the phenomenological impact of the resummation to next-to-next-to-leading logarithmic (NNLL) accuracy. We found that these corrections increase the total cross section and the differential distributions with respect to NLO calculations of the same observables.

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## Cross section and coupling measurements with the ATLAS detector for the 125 GeV Higgs Boson

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Detailed measurements of the properties of the 125 GeV Higgs boson are fundamental for the understanding of the electroweak symmetry breaking mechanism. Measurements of the Higgs boson allow to study the gauge, loop induced and Yukawa couplings of the Higgs boson both in production and decay modes. This talk summarizes recent ATLAS measurements of the 125 GeV Higgs boson.  
22/05/2017, 10:55 Michael D

Hard QCD and EW / 21

## Higher-order corrections for the three-jet rate in electron-positron annihilation using the (anti)-kt algorithm

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We present our next-to-next-to-leading order result performed in the CoLoRFulNNLO subtraction scheme for the three jet rate in electron-positron annihilation into three jets using the exclusive kt clustering algorithm. Results matched with next-to-double logarithmic resummation are also shown compared to OPAL data. In addition we present our predictions using the anti-kt algorithm at next-to-next-to-leading order in perturbation theory matched with next-to-double logarithmic resummed prediction for the first time.

**Top, heavy quarks and searches / 22**

## Measurement of single top quark production with CMS

**Author:** Collaboration CMS<sup>None</sup>

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Several measurements of single top quark production in proton-proton collisions at the LHC at centre-of-mass energies of 7, 8 and 13 TeV, using data collected with the CMS experiment, are presented. The analyses investigate separately the productions of top via t-channel exchange, in association with a W boson (tW) or via the s-channel. Final states with at least one charged lepton and one b-jet are explored to measure inclusive production cross sections. Fiducial and differential cross section measurements in the t-channel are also reported. The measurements can be used to constrain directly the  $V_{tb}$  CKM matrix element by comparing with the most precise standard model theory predictions. Measurements of rare processes involving a top quark and a neutral EWK boson (Z or photon) are also discussed.

**Top, heavy quarks and searches / 23**

## Top quark event modelling and generators in CMS

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State-of-the-art theoretical predictions accurate to next-to-leading order QCD interfaced with Pythia8 and Herwig++ event generators are tested by comparing the unfolded  $t\bar{t}$  differential data collected with the CMS detector at 8 and 13 TeV. These predictions are also compared with the underlying event activity distributions in  $t\bar{t}$  events using CMS proton-proton data collected at a center of mass energy of 13 TeV. Studies of b-quark fragmentation in  $t\bar{t}$  events are furthermore presented.

**Top, heavy quarks and searches / 24**

## CMS measurements of top quark pair production

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Measurements of the inclusive and differential top quark pair production cross section in proton-proton collisions at 5.02 TeV, 7 TeV, 8 TeV and 13 TeV are presented using the CMS detector. The total cross section is measured using the lepton+jets, dilepton and fully hadronic channels, including the tau-dilepton and tau+jets modes. Indirect constraints on both the top quark mass and  $\alpha_S$  are obtained through their relation to the inclusive cross section. Measurements of top quark pair production in addition with jets, including heavy-flavoured jets are also presented. In addition, differential cross sections are measured and are given as functions of various kinematic observables, including the transverse momentum and rapidity of the (anti)top quark and the top-antitop system and the jets and leptons of the event final state. The measurements are extended to the TeV range using jet substructure techniques to exploit the boosted regime. The multiplicity and kinematic distributions of the jets produced in addition to the top pair are also investigated. The results are combined and confronted with precise theory calculations.

**Hard QCD and EW / 25**

## Vector boson scattering at next-to-leading order

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**Co-authors:** Ansgar Denner ; Mathieu Pellen<sup>2</sup>

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Vector boson scattering at the LHC has recently been discovered in the process  $pp \rightarrow \mu^+ \nu_\mu e^+ \nu_e$ , the so-called same-sign WW channel. This opens a new window for studying the nature of electroweak symmetry breaking and the role of the Higgs boson. Precision predictions for this process are thus of great importance. In this talk, the electroweak corrections at next-to-leading order for the same-sign WW channel will be presented. Reaching  $-16\%$  at the level of the inclusive cross section, they turn out to be surprisingly large and of similar size as the corresponding NLO QCD corrections. At the level of differential distributions, they are even more enhanced in the high-energy regime. We will present predictions that combine both NLO EW and QCD corrections, and will review their different behaviour and origin. A phenomenological analysis with realistic acceptance cuts is shown.

Top, heavy quarks and searches / 26

## Automation of NLO QCD and EW corrections with Sherpa and Recola

**Author:** Benedikt Biedermann<sup>1</sup>

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In this talk, the combination of the one-loop matrix-element generator Recola with the multipurpose Monte Carlo program Sherpa is presented. Since both programs are highly automated, the resulting Sherpa+Recola framework allows for the computation of—in principle—any Standard Model process at both NLO QCD and EW accuracy. The reliability of the Sherpa+Recola framework will be demonstrated via the NLO QCD and electroweak computation of off-shell Z-boson pair production and the production of a top-quark pair in association with a Higgs boson. As the implementation is fully automatised, this makes it a perfect tool for both experimentalists and theorists who want to use state-of-the-art predictions at NLO accuracy in their analyses.

Top, heavy quarks and searches / 27

## Off-shell ttj production and top quark mass measurement

**Author:** Heribertus Bayu Hartanto<sup>1</sup>

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We present a NLO QCD calculation of  $t\bar{t}j$  production at the LHC in the dilepton channel, where all non-resonant diagrams, interferences and off-shell effects of the top quark are included. We investigate different choice of dynamical scales in order to stabilize the perturbative convergence of the differential distributions far away from the threshold. We will also discuss the application of our calculation to the top quark mass measurement study and compare them with different theoretical predictions.

**Heavy ions / 28**

## Charmed meson and baryon production in pp collisions with ALICE at the LHC

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Heavy charm and beauty quarks are sensitive probes to study the Quark-Gluon Plasma produced in high-energy heavy-ion collisions. Because of their large masses, they are produced in the initial stage of the collision and therefore explore the entire evolution of the produced medium. ALICE, A Large Ion Collider Experiment located at the Large Hadron Collider at CERN, is a dedicated experiment for heavy-ion collisions. Besides Pb-Pb and p-Pb collisions, ALICE also studies heavy-flavour production in pp collisions.

The measurements of heavy-flavour production in pp collisions are an important test for perturbative QCD calculations. At low  $p_T$ , where the theoretical uncertainties are still relatively large, heavy-flavour production is dominated by low- $x$  gluons, so measurements in this region can provide necessary constraints on the pQCD calculations. Measurements in pp collisions are also essential as baseline for heavy-ion analyses. For example the nuclear modification factor  $R_{AA}$ , which measures the effect of in-medium energy loss, uses the proton-proton reference measurement.

In this talk, the status of open charm meson and baryon production measurements in pp collisions at  $\sqrt{s} = 5.02, 7, 8$  and 13 TeV with the ALICE experiment during LHC Run-1 and Run-2 will be presented. These results will include the production cross section of D mesons at all three energies, multiplicity measurements at  $\sqrt{s} = 7$  TeV and the measurements of the baryons  $\Lambda_c$  and  $\Xi_c$  at  $\sqrt{s} = 7$  TeV. Comparisons with theoretical model predictions will be shown.

**Resummation and Monte Carlo generators / 29**

## Analytical and numerical approaches to (N)LL resummation

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While large logarithms arising from the IR structure of QCD can be resummed to higher logarithmic accuracy for specific observables, numerical calculations based on parton showers are formally correct to



LL only. However, they incorporate additional effects like local momentum conservation, which are beyond this formal accuracy. As a first step towards a quantitative study of these effects, a final state parton shower is constructed which implements the exact NLL result for certain observables. It is then used to obtain a detailed comparison of the numerical size of approximations made in analytic NLL calculations.

## Hard QCD and EW / 30

### Analysis of QED/EW effects in hadronic processes beyond LO

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In this talk, we describe the computation of higher-order QED effects relevant in hadronic collisions. We start with a brief discussion about the calculation of mixed QCD-QED one-loop contributions to the Altarelli-Parisi splittings functions. Then, we explain how to extend the DGLAP equations to deal with new parton distributions, emphasizing the consequences of the novel corrections in the determination (and evolution) of the photon distributions. Finally, we present an estimation of the effects in some physical processes studied at the LHC.

## Heavy ions / 31

### PHENIX results on three particle Bose-Einstein correlations in $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions

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Bose-Einstein correlations of identical hadrons reveal information about hadron creation from the sQGP formed in ultrarelativistic heavy ion collisions. The measurement of three particle correlations may in particular shed light on hadron creation mechanisms beyond thermal/chaotic emission. In this talk we show the status of PHENIX measurements of three pion correlations as a function of momentum differences within the triplets. We analyze their shape through the assumption of Levy sources and a proper treatment of the Coulomb interaction within the triplets. We determine Levy parameters  $R$ ,  $\alpha$  and  $\lambda_3$ , which give source size, shape and correlation strength, respectively. The  $\lambda_3$  encodes information about hadron creation mechanism, together with two particle correlation strength  $\lambda_2$ . From a consistent analysis of two- and three-particle correlation strength we may be able to establish an experimental measure of thermalization and coherence in the source.

## Parton Distribution Functions and Soft QCD / 32

## Markov Chain Monte Carlo technics applied to Parton Distribution Functions determination: proof of concept

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Abstract:

We have developed a new procedure to determine Parton Distribution Functions (PDFs) and their uncertainties, based on Markov Chain Monte Carlo methods. We will show in this talk how we can replace the standard  $\chi^2$  minimization by procedures grounded on Statistical Methods, and on Bayesian inference in particular, thus offering additional insight into the rich field of PDFs. The formulation of PDFs determination in terms of Bayesian inference, the Monte Carlo algorithm we have implemented in the xFitter code, and the first results we have obtained will be presented.

**Heavy ions / 33**

## HIJING++ a New Generation of Hadron Interaction Generator for the Future's Nucleus-Nucleus Collisions at High-energies

**Authors:** Gergely Gabor Barnafoldi<sup>1</sup>; Gabor Biro<sup>2</sup>; Peter Levai<sup>2</sup>; Miklos Gyulassy<sup>3</sup>; Xin-Nian Wang<sup>4</sup>; Gábor Papp<sup>5</sup>; Guoyang Ma<sup>6</sup>; Ben-Wei Zhang<sup>7</sup>; Szilveszter Miklos Harangozo<sup>2</sup>

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In the high-energy heavy-ion physics community the FORTRAN based HIJING Heavy Ion Jet Interaction Generator code is commonly used, originally developed by Xin-Nian Wang and Miklos Gyulassy [1] – more than 2 decades ago. Although it was intended to describe the heavy-ion collisions occurring at RHIC energies, it has still many applications with today's higher collision energies. However, the technological advancement nowadays makes it clear that the upgrade of the code is getting more and more important. The Budapest–Berkeley–Wuhan collaboration has already started this key development task.

The new, C++ based and soon-to-be-published HIJING++ that we introduce will be the successor of the original HIJING[2]. It will be a state-of-the-art Monte Carlo code with all of the capabilities of the original event generator and much more. It is designed to be future-proof in the sense of computer hardware and software as well.

In this talk we present the current state of the development and give an outlook of the forthcoming physics and computing features. We also present our first predictions for hadron production at the 8.16 TeV c.m. energy in p+Pb collisions [3].

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Heavy ions / 34

## PHENIX results on Bose-Einstein correlation functions using a Levy analysis in Au+Au collisions at RHIC

Author: Sándor Lökös<sup>None</sup>

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The RHIC beam energy scan program allows for the investigation of the phase diagram of QCD matter by varying the beam energy in the region where the change from crossover to first order phase transition is expected to occur. The nature of the quark-hadron transition can be studied through analyzing the space-time structure of the hadron emission source. One of the best tools to gain information about the source is the measurement of Bose-Einstein or HBT correlations of identical bosons. In recent measurements, we utilize Levy-type sources to describe the measured correlation functions. In this presentation we report the detailed measurement of the Levy source parameters as a function of transverse mass in Au+Au collisions at  $\sqrt{s_{NN}} = 39, 62$  and 200 GeV. In particular we discuss the observation of a new scaling parameter,  $R_{\text{hat}}$ , as well as the shape of the correlation strength versus transverse mass ( $\lambda(\text{mT})$ ) and its relation to the  $\eta'$  mass.

Heavy ions / 35

## Non-extensive Statistics Motivated Fragmentation for Hadron Production in High-Energy Collisions

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A global theoretical description of hadron's transverse momentum spectra in high-energy particle collisions is still an open question today. However, identified hadron spectra measured in the experiments can be described well with non-extensive statistical approach. This method is motivated by the fact that, negative binomial (NBD) multiplicity of the particle number distribution results the measured Tsallis–Pareto particle energy distribution [1; 2].

Theoretical analysis of the identified hadron spectra led us to understand the micro- and macroscopical processes by comparing parameters of the hadronization models. The Tsallis–Pareto distribution describes perfectly the hadron spectra for all particle- and collision-energies Ref. [3; 4]. The values of the parameters of the fitted distributions correspond to the expected properties of the colliding systems, like particle multiplicities and finite size effects.

We investigated the calculated and simulated hadron spectra in proton-proton collisions and we determined the parameters of the Tsallis–Pareto distributions. We have shown also, that these results correspond with the experimental data. Investigating the values and energy dependence of the parameters, motivated us to make a new

parametrization of the fragmentation functions, which idea fit nicely to the non-extensive phenomena of a possible novel hadronization model Ref. [5].

Testing this non-extensive-based fragmentation, we included it to a perturbative QCD calculation and compares the results to other fragmentation parametrization and experimental data. Our results are pointed out that our theoretical model corresponds to the experimental data, confirming the non-extensive, Tsallis-like fragmentation parametrization.

References:

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**Resummation and Monte Carlo generators / 36**

## Bottom mass effects on the Z boson transverse momentum and their implications for the W mass measurements

**Author:** Emanuele Angelo Bagnaschi<sup>1</sup>

**Co-authors:** Alessandro Vicini<sup>2</sup>; Marco Zaro<sup>3</sup>; Fabio Maltoni<sup>4</sup>

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The inclusive transverse momentum spectrum (pt) of the Z boson is measured with high precision at the LHC and for this reason it is used a standard candle to tune Monte Carlo event generators. In turn, this implies that a change in theoretical description of the Z pt affects MC predictions used in other SM precision measurements, such as the W mass measurement. One of the uncertainties that currently affects the theoretical prediction comes from the fact that in the usually used five flavor scheme (5FS), heavy flavors are treated as massless. In this work we aim to improve the theoretical prediction of this observable by studying the effect of consistently including the description of the inclusive Z boson transverse momentum coming from the four flavor scheme (4FS) computation of Z in association with b bbar (where the bottom quarks are massive) on the top of the 5FS scheme description of the neutral current Drell-Yan. Finally, we estimate the effect of these effects on the measurement of the W mass.

**Resummation and Monte Carlo generators / 37**

## Precision QCD simulations for the LHC with Sherpa

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The improvements of Monte-Carlo event generators in the last decade enable quantitative predictions for the LHC at an unprecedented accuracy.

Combining matrix elements at next-to-leading order in QCD with parton-shower emissions (“matching”) and using (N)LO matrix elements for hard emissions at different final-state multiplicities (“merging”) led to considerably reduced theoretical uncertainties. There are also ongoing efforts to integrate NNLO matrix elements within these algorithms, reducing the theory uncertainties even more.

In my talk I will review the state-of-the-art of these methods in the context of the Monte-Carlo event generator Sherpa, along with other recent Sherpa developments. In particular, I will present the newly added reweighting methods that allow to efficiently determine the QCD matrix-element and parton-shower uncertainties without generating additional Monte-Carlo samples.

**Top, heavy quarks and searches / 38**

## Soft gluon resummation for the associated production of a top quark pair with a Higgs boson at the LHC

**Authors:** Anna Kulesza<sup>None</sup>; Leszek Motyka<sup>None</sup>; Tomasz Stebel<sup>None</sup>; Vincent Theeuwes<sup>None</sup>

The measurement of the associated production of a Higgs boson with a pair of top quarks is among the highest priorities of the current LHC physics program. In this talk latest results for threshold resummation of soft gluon corrections for the  $pp \rightarrow t\bar{t}H$  process will be presented. The resummation is carried out at next-to-next-to-leading-logarithmic accuracy using the direct QCD Mellin space technique in the three-particle invariant mass kinematics. Numerical predictions for total inclusive cross sections and invariant mass distributions for the associated production of top quarks with a Higgs boson or a heavy vector boson at the LHC will be discussed.

**Resummation and Monte Carlo generators / 40**

## Parton densities from a parton branching solution of QCD evolution equations

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QCD evolution equations can be recast in terms of parton branching processes. We present a new numerical solution of the equations and show, that this method reproduces the semi-analytical solutions.

We discuss numerical effects of the kinematic boundary of resolvable branchings on the resulting parton distribution functions. We show, how this method can be used to determine Transverse Momentum Dependent (TMD) parton distribution functions, in addition to the usual integrated parton

distributions functions.

We also show, that a very good fit to high precision HERA data can be obtained over a large range in  $x$  and  $Q^2$ .

**Resummation and Monte Carlo generators / 41**

## **Simpler WW production with a jet veto**

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I present a new method to compute the cross section for WW production with a jet veto in QCD, fully exclusive in the decay products of the WW pair. The method is independent of the physics underlying the production of the WW pair, and allows for the interface with any NLO event generator.

**Higgs physics and searches / 42**

## **A light $0^{++}$ and other hadronic resonance from a new strongly interacting sector exhibiting large scale separation**

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Many theories describing physics beyond the Standard Model rely on a large separation of scales. Large scale separation arises in models with mass-split flavors if the system is conformal in the ultraviolet but chirally broken in the infrared. Because of the conformal fixed point, these systems exhibit hyperscaling and a highly constrained resonance spectrum.

In numerical simulations we investigate the light-light and heavy-heavy spectrum, confirm our expectation on hyperscaling, and find, moreover, that the iso-singlet scalar ( $0^{++}$ ) is “light” and lies below the vector resonance. The spectrum is qualitatively different from QCD and exhibits e.g. quarkonia with masses not proportional to the constituent quark mass. We expect these resonances to be within reach of the LHC.

**Higgs physics and searches / 43**

## **Top-bottom interference effects in Higgs boson production**

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“The study of Higgs boson properties form an important part of the LHC program. These studies are not only important for a better understanding of electroweak symmetry breaking mechanism but also for BSM searches. For example, most recently a strategy has been proposed to use LHC measurements of the Higgs transverse momentum distribution to constrain the Yukawa couplings of light-generation quarks to the Higgs boson. In this talk I will present the calculation of NLO QCD corrections of the top-bottom interference contribution to Higgs plus jet production at the LHC. The calculation involved computing two-loop Feynman integrals expanded in a small bottom mass, which we performed with the differential equation method and that I will elaborate upon. I will also show our results for the NLO top-bottom interference contribution to the Higgs transverse momentum distribution.”

**Top, heavy quarks and searches / 44**

## Measurements of the top quark properties at decay with CMS

**Author:** Collaboration CMS<sup>None</sup>

**Corresponding Author:** silvano.tosi@cern.ch

Several measurements of top quark properties are presented using data collected by the CMS experiment at different centre-of-mass-energies. The properties are mostly probed in the decay of the top quarks. The  $Wtb$  couplings are probed by measuring the helicity fractions in single top and  $t\bar{t}$  topologies or by inspecting a V-A vertex structure of the coupling. Furthermore, searches for flavor-changing neutral currents involving top quarks are discussed including  $tZq$ ,  $t\gamma q$ ,  $tgq$  and  $tHq$  couplings. Limits are set on anomalous top couplings and the results are furthermore re-interpreted as searches for new physics inducing deviations from the standard model predictions.

**Top, heavy quarks and searches / 45**

## Measurements of the top quark properties with CMS

Several measurements of top quark properties are presented using data collected by the CMS experiment at different centre-of-mass-energies. The properties are mostly probed in production of the top quarks. The charge asymmetry is measured inclusively and differentially probing anomalous couplings to the gluons at production mode. These measurements are extended searching for asymmetries in CP-odd operators in production and decay. The measurement of the spin density matrix in different final states (lepton+jets and dileptons) is discussed as well as the measurement of the top quark polarization in single top and  $t\bar{t}$  events. The results are compared to the state-of-the-art predictions, when available, and re-interpreted as searches for new physics inducing deviations from the standard model predictions.

**Top, heavy quarks and searches / 46**

## Measurements of the associated production of top quark pairs with bosons or other top quarks

**Author:** Collaboration CMS<sup>None</sup>

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A comprehensive set of measurements of top quark pair production in association with EWK bosons ( $W$ ,  $Z$  or  $\gamma$ ) is presented at different centre-of-mass energies. The results are compared to the theory predictions and re-interpreted as searches for new physics inducing deviations from the standard model predictions using an effective field theory approach. The status of the search for double- $t\bar{t}$  pair production combining different final states is also reported.

**Top, heavy quarks and searches / 47**

## Top quark mass measurements at CMS

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Measurements of the top quark mass and width using proton-proton collisions at the LHC at centre-of-mass energies of 7, 8 and 13 TeV are presented. The analyses used different decay channels and production modes of the top quark. Several techniques are investigated based on the reconstruction of the top kinematics from final state products, using leptonic decays with a  $J/\psi$ , the shapes of top quark decay distributions, or comparing the production rates to the theory expectations, among others. The results are employed to determine the top quark mass and the results furthermore combined and compared to the world average. The dependence of the mass measurement on the kinematic phase space is furthermore investigated, including measuring the difference between the masses of top and antitop quarks.

**Hard QCD and EW / 48**

## Full-colour decompositions for loop amplitudes in Yang-Mills theory

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I will present a general method to account for full colour dependence Yang-Mills amplitudes at loop level. The method fits most naturally into the framework of multi-loop integrand reduction and in a nutshell amounts to consistently retaining the colour structures of the unitarity cuts from which the integrand is gradually constructed. I will discuss connections to loop-level Kleiss-Kuijf relations and implications for cancellation of nontrivial symmetry factors at two loops. I will illustrate this technique on the recent calculation of the two-loop five-gluon amplitude with all positive-helicity gluons, as well as a three-loop example in supersymmetric Yang-Mills.

**Top, heavy quarks and searches / 49**

## Search for heavy resonances decaying to top quarks

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Searches for new resonances that decay either to pairs of top quarks or a top and a b-quark will be presented. The searches are performed with the ATLAS experiment at the LHC using proton-proton collision data collected in 2015 and 2016 with a centre-of-mass energy of 13 TeV. The invariant mass spectrum of hypothetical resonances are examined for local excesses or deficits that are inconsistent with the Standard Model prediction.

**Parton Distribution Functions and Soft QCD / 50**

## Multi-differential jet cross sections in CMS

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We present measurements of multi-differential Jet cross sections over a wide range in transverse momenta from inclusive jets to multi-jet final states. We present studies on the impact these measurements have on the determination of the strong coupling alphas as well as on parton density functions. We also show angular correlations in multi-jet events at highest center-of-mass energies and compare the measurements to theoretical predictions including higher order parton radiation and coherence effects.

**Parton Distribution Functions and Soft QCD / 51**

## Measurements of event properties with jets in CMS

**Author:** CMS Collaboration<sup>None</sup>

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We present results on measurements of characteristics of events with jets, from jet-charge over investigations of shapes to jet mass distributions. The measurements are compared to theoretical prediction including those matched to parton shower and hadronization.

**Higgs physics and searches / 52**

## Modeling BSM effects on the Higgs transverse-momentum spectrum in an EFT approach

**Author:** Agnieszka Janina Ilnicka<sup>1</sup>

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After the Higgs boson discovery, LHC can be used as a precision machine to explore its properties. Indeed, in case new resonances will not be found, the only access to New Physics would be via measuring small deviations from the SM predictions. A consistent approach is provided by a bottom-up Effective Field Theory, with dimension six operators built of Standard Model fields (SMEFT). We discuss how this approach works in case of the transverse momentum spectrum of the Higgs particle. In our calculation we augmented the Standard Model with three additional operators describing modifications of the top and bottom Yukawa couplings, and a point-like Higgs coupling to gluons. We discuss also the impact of the chromomagnetic operator.

**Higgs physics and searches / 53****Differential distributions for Higgs production at higher orders in QCD****Author:** Simone Lionetti<sup>1</sup><sup>1</sup> *ETH Zürich***Corresponding Author:** lionetti@phys.ethz.ch

I will present a computation of the cross section for Higgs production via gluon fusion that is differential in the Higgs momentum and inclusive with respect to associated QCD radiation.

This calculation is carried out through NNLO in perturbative QCD and includes the  $O(d-4)$  pieces which are necessary for UV renormalisation and mass factorisation at N<sup>3</sup>LO.

First, I will discuss the restriction to observables that only depend on the Higgs kinematics. This choice renders the subtraction of infrared singularities straightforward and makes our strategy well suited to be generalised to higher orders.

I will then show some predictions for differential cross sections for Higgs production in the fiducial volume, which can be directly obtained including the decay of the Higgs on top of the discussed computation.

**Higgs physics and searches / 54****Higgs transverse-momentum resummation at N<sup>3</sup>LL****Authors:** Wojciech Bizon<sup>1</sup>; Pier Francesco Monni<sup>2</sup>; Emanuele Re<sup>None</sup>; Luca Rottoli<sup>3</sup>; Paolo Torrielli<sup>4</sup><sup>1</sup> *University of Oxford (GB)*<sup>2</sup> *CERN*<sup>3</sup> *University of Oxford*<sup>4</sup> *Universita e INFN Torino (IT)***Corresponding Authors:** wojciech.jozef.bizon@cern.ch, luca.rottoli@cern.ch, pier.francesco.monni@cern.ch, paolo.torrielli@gmail.com, emanuele.re@cern.ch

We discuss a formalism for the resummation of the Higgs transverse momentum, and more in general of inclusive transverse observables, in direct space up to N<sup>3</sup>LL accuracy. The talk is based on 1604.02191 and 1705.09127.

**Parton Distribution Functions and Soft QCD / 55****Exclusive physics results at CMS****Author:** Collaboration CMS<sup>None</sup>**Co-author:** Oliver Suranyi<sup>1</sup><sup>1</sup> *Eötvös Loránd University***Corresponding Authors:** suranyi.oliver@cern.ch, stosi@cern.ch

In high energy physics, exclusive processes are special type of collisions, where both colliding particles remain intact and we observe all of the produced particles. These can be either electroweak

(two-photon fusion), strong (double pomeron exchange) or mixed electromagnetic and strong (photo-production) processes. One of the greatest advantage of these collisions is that there are constraints on quantum numbers of final state. This property is useful in a wide variety of high energy researches, such as search for glueballs or the measurement of anomalous quartic gauge couplings. This talk introduces three results from CMS experiment: 1. Search for W-boson pairs produced via two-photon fusion in pp collisions and limits on anomalous quartic gauge couplings. 2. Rho and Upsilon photoproduction in ultraperipheral pPb collisions. 3. Di-pion production via double pomeron exchange and photoproduction in pp collisions at 5, 7 and 13 TeV.

**Top, heavy quarks and searches / 56**

## **Soft and Coulomb effects in top-quark pair production beyond NNLO**

**Author:** Christian Schwinn<sup>1</sup>

<sup>1</sup> *RWTH Aachen University*

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Current predictions for the total top-quark pair production cross section are based on NNLO QCD corrections with NNLL soft-gluon resummation. I will discuss the perspectives to go beyond this approximation by using known ingredients for N3LL soft-gluon resummation and Coulomb corrections.

**Parton Distribution Functions and Soft QCD / 57**

## **Damping the energy-rise of the proton-proton cross section: interplay of perturbative and nonperturbative effects**

**Author:** Sergey Ostapchenko<sup>1</sup>

<sup>1</sup> *Frankfurt Institute for Advanced Studies (FIAS)*

**Corresponding Author:** sergei@tf.phys.ntnu.no

The impact of nonlinear interaction effects on the total proton-proton cross section is studied. In particular, the relative roles of the perturbative and nonperturbative parton splitting mechanisms are investigated. Additionally, the importance of dynamical higher twist corrections to parton production processes is demonstrated.

**Hard QCD and EW / 62**

## **Non-standard heavy vector bosons at the LHC**

**Author:** Gennaro Corcella<sup>1</sup>

<sup>1</sup> *INFN - LNF*

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Searching for heavy vector bosons is one of the challenging objectives of the LHC: I will discuss two scenarios which have not been investigated yet by the experimental collaborations. The first scenario

consists in searching for  $Z'$  bosons, predicted by U(1) GUT-inspired models, by investigating its possible BSM decays, namely supersymmetric decays, leading to resonant final states with charged leptons and missing energy. Afterwards, I will present a recent work, carried out in the framework of the 331 model, which predicts novel doubly-charged bosons  $Y$  and yields final states with two same-sign lepton pairs, accompanied by two jets, which can be easily separated from the Standard Model backgrounds.

**Hard QCD and EW / 63**

## Energy-energy correlation at NNLL+NNLO

**Author:** Zoltán Tulipánt<sup>1</sup>

**Co-authors:** Adam Kardos<sup>1</sup>; Gabor Somogyi<sup>2</sup>

<sup>1</sup> *University of Debrecen*

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In this talk we consider the back-to-back region of the energy-energy correlation in  $e^+e^-$  collisions and present the matching of the next-to-next-to-leading logarithmic (NNLL) approximation with the recently computed fixed next-to-next-to-leading order (NNLO) corrections. We perform the matching in the log R scheme. We compare our results to precise LEP and SLC data, and find that the inclusion of the NNLO corrections has a sizeable impact on the extracted value of  $\alpha_S(M_Z)$ .

**Resummation and Monte Carlo generators / 64**

## Heavy quark radiation in NLO+PS POWHEG generators

**Authors:** Francesco Tramontano<sup>1</sup>; Luca Buonocore<sup>2</sup>; Paolo Nason<sup>3</sup>

<sup>1</sup> *Universita e INFN, Napoli (IT)*

<sup>2</sup> *INFN - National Institute for Nuclear Physics*

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We discuss about radiation from heavy quarks in the context of next-to-leading order calculations matched to parton shower generators. A new algorithm for radiation from massive quarks is presented that offers advantages over the one previously employed. We implement the algorithm in the framework of the POWHEG-BOX, and compare it with the previous one in the case of the hvq generator for bottom production in hadronic collisions, and in the case of the bb4l generator for top production and decays.

**Higgs physics and searches / 65**

## Status of QCD corrections for BSM Higgs Physics

**Author:** Emanuele Angelo Bagnaschi<sup>1</sup>

<sup>1</sup> *DESY Hamburg*

**Corresponding Author:** emanuele.bagnaschi@desy.de

In this talk we review the current status of QCD corrections for Higgs production and decay at the LHC in the context of BSM physics. These corrections are important for two reasons. First, to appreciate possible deviations in the properties of the observed SM-like states due to the effect colored-BSM particles, such as stops, from virtual corrections. Second, QCD corrections are important for the correct characterization of the signal of possible, new, BSM Higgs states at the LHC.

**Higgs physics and searches / 66**

## H→4l measurements at ATLAS and CMS

**Author:** CMS<sup>None</sup>

**Corresponding Author:** mitselmakher@phys.ufl.edu

This talk will describe measurements using Higgs boson decays to 4 leptons at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 67**

## H→WW measurements at ATLAS and CMS

**Author:** CMS<sup>None</sup>

**Corresponding Author:** l.russo@cern.ch

This talk will describe measurements and searches using Higgs boson decays to two W bosons at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 68**

## H→bb̄ analyses at ATLAS and CMS

**Author:** CMS<sup>None</sup>

**Corresponding Author:** rostyslav.shevchenko@cern.ch

This talk will describe searches for Higgs bosons decaying into two b-quarks at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 69**

## **ttH searches at ATLAS and CMS**

**Author:** CMS<sup>None</sup>

**Corresponding Author:** thomas.strebler@llr.in2p3.fr

This talk will describe the search for Higgs production in association with a tt-bar pair at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 70**

## **BSM Higgs searches at ATLAS and CMS**

**Author:** CMS<sup>None</sup>

**Corresponding Author:** t.williams@cern.ch

This talk will describe searches for additional Higgs bosons at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 71**

## **New physics searches in Higgs final states at ATLAS and CMS**

**Author:** CMS<sup>None</sup>

**Corresponding Author:** marton.bartok@cern.ch

This talk will describe searches for physics beyond the SM in final states with Higgs bosons at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 72**

## **H->gamgam measurements at ATLAS and CMS**

**Author:** ATLAS<sup>None</sup>

**Corresponding Author:** hongtao.yang@cern.ch

This talk will describe measurements and searches using Higgs boson decays to two photons at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 73**

## **H->tautau analyses at ATLAS and CMS**

**Author:** ATLAS<sup>None</sup>

**Corresponding Author:** peter.wagner@cern.ch

This talk will describe analysis using Higgs boson decays to two taus at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 74**

## **Higgs results from the combination at ATLAS and at CMS**

**Author:** ATLAS<sup>None</sup>

**Corresponding Author:** jlacey@cern.ch

This talk will describe the combination of Higgs results from different decay channels at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 75**

## **Searches for rare and BSM decays at ATLAS and CMS**

**Author:** ATLAS<sup>None</sup>

**Corresponding Author:** pedro.henrique.sales.de.bruin@cern.ch

This talk will describe searches for rare and beyond the Standard Model decays at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 76**

## **Di-Higgs searches at ATLAS and CMS**

**Author:** ATLAS<sup>None</sup>

**Corresponding Author:** magdalena.slawinska@cern.ch

This talk will describe the searches for di-Higgs production at the ATLAS and CMS experiments, presenting the analysis methods and results. Emphasis will also be put on the QCD aspects that are relevant for the analyses.

**Higgs physics and searches / 77**

## **Experimentalists' wishes for theoretical calculations and tools for analyses**

**Author:** TBD<sup>None</sup>

This talk will give an overview of how theoretical calculations and tools are used in measurements and searches in Higgs physics. It will in particular focus on showing where improved theoretical calculations and tools

**Heavy ions / 78**

## **Heavy-flavour production in heavy-ion collisions at the ALICE experiment**

**Authors:** Robert Vertesi<sup>1</sup>; ALICE collaboration<sup>None</sup>

<sup>1</sup> *Hungarian Academy of Sciences (HU)*

**Corresponding Author:** vertesi.robert@wigner.mta.hu

Heavy-flavour (beauty and charm) quarks are produced almost exclusively in initial hard processes, and their yields remain largely unchanged throughout a heavy-ion reaction. Nevertheless, they interact with the nuclear matter in all the stages of its evolution. Thus, heavy quarks serve as ideal self-generated penetrating probes of the strongly interacting Quark-Gluon Plasma (QGP). Complementary measurements of the nuclear modification factor  $R_{AA}$  and the azimuthal anisotropy parameter  $v_2$ , compared to different model calculations, reveal the properties of heavy quark transport, provide information about energy loss mechanisms and also about the participation of heavy quarks in the collective motion within the QGP. Recent  $R_{AA}$  and  $v_2$  measurements of D mesons and heavy-flavour hadron decay electrons at mid-rapidity, as well as heavy-flavour hadron decay muons at forward rapidity, will be overviewed in this talk, including Pb-Pb collisions at  $\sqrt{s_{NN}}=2.76$  TeV and new preliminary results at  $\sqrt{s}=5.02$  TeV from the Run-2 phase.

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## **Higgs physics results from a QCD perspective**

**Corresponding Author:** dezso.horvath@cern.ch

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## **Higgs physics results from a QCD perspective**

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## **Higgs physics from the theory perspective**

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## **Generators**

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## **Measurements in heavy ion collisions**

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## **Boosted topologies within and beyond the SM**

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## **Deep Learning QCD Jets**

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## **Heavy quark physics**

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## **Heavy quarks**

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## **Electroweak corrections**

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## Results on EW gauge bosons and jet production

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## Parton Distribution Functions

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## Soft QCD, diffractive and exclusive results from the LHC

Corresponding Author: gabor.veres@cern.ch

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## Top quark measurements at the LHC

Corresponding Author: javier.cuevas.maestro@cern.ch

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## SCET and resummation

Corresponding Author: frank.tackmann@desy.de

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## W mass measurement with the ATLAS detector

Author: ATLAS Collaboration<sup>None</sup>

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## Summary

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## Di-Higgs searches at ATLAS and CMS

Higgs physics and searches / 98

### Parton shower and finite-top mass effects in Higgs pair production

**Corresponding Author:** kerner@mpp.mpg.de

Studying the pair production of Higgs bosons at the LHC is important as it is sensitive to the Higgs trilinear coupling. It therefore allows for a direct test of the Higgs potential and the mechanism of electroweak symmetry breaking. Since the heavy top limit provides only a poor description of Higgs boson pair production, a precise theoretical description of this process requires the evaluation of massive top loops at leading order, and massive two-loop diagrams at NLO. In this talk we will present a calculation of the NLO cross section for Higgs boson pairs, retaining the full dependence on the top-quark mass, and supplementing it with a parton shower. We further investigate the finite top-quark mass effects and the impact of the parton shower on several differential observables.

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### Double Higgs Production in the Vector Boson Fusion Channel

**Corresponding Author:** fady.bishara@physics.ox.ac.uk

The LHC experiments have, so far, measured many of the Higgs couplings and found excellent agreement with the minimally-realized electroweak symmetry breaking (EWSB) mechanism in the Standard Model. Nevertheless, there are important couplings that are currently out of reach which test the nature of EWSB and fermion mass generation. This talk will focus on one such coupling: the  $hhVV$  coupling. This is important because deviations of the  $hhVV$  coupling from the SM would signal non-linearities in the Higgs interactions and herald new physics at higher energies. As I will show, double Higgs production in VBF at the LHC can provide such a test at the 20% level by the end of the high luminosity run while a percent level constraint can be obtained at a future circular collider.

Top, heavy quarks and searches / 100

### Recent results on the calculation of three-loop operator matrix elements with two masses

**Corresponding Author:** abilio.de.freitas@desy.de

We report on our recent progress on the calculation of massive operator matrix elements (OMEs), which at three loop level receive contributions from Feynman diagrams containing two heavy quark lines of different masses. These OMEs are needed in order to obtain the corresponding contributions for the massive Wilson coefficients in deep inelastic scattering at large momentum transfer. They are also needed to describe the variable flavor number scheme at three loops, where the charm and

bottom quarks cannot be decoupled one at a time, since the ratio of the corresponding masses is not small enough. We show the full result for the two-mass non-singlet and pure singlet OMEs, and describe in detail the methods used to calculate the scalar Feynman integrals required to obtain the gluonic OMEs.

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## Fixed-order QCD corrections

Corresponding Author: daniel.de.florian@cern.ch

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## Towards multi-jet processes at NNLO

Corresponding Author: jmhenn@ias.edu

Top, heavy quarks and searches / 103

## Measurements of the associated production of top quark pairs with bosons or other top quarks

Corresponding Author: javier.cuevas.maestro@cern.ch

A comprehensive set of measurements of top quark pair production in association with EWK bosons (W, Z or  $\gamma$ ) is presented at different centre-of-mass energies. The results are compared to the theory predictions and re-interpreted as searches for new physics inducing deviations from the standard model predictions using an effective field theory approach. The status of the search for double-ttbar pair production combining different final states is also reported.

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## Recent results on the calculation of three-loop operator matrix elements with two masses

Authors: Abilio De Freitas<sup>1</sup>; Johannes Bluemlein<sup>1</sup>; Alexander Hasselhuhn<sup>2</sup>; Jakob Ablinger<sup>3</sup>; Carsten Schneider<sup>3</sup>; Fabian Wissbrock<sup>4</sup>

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We report on our recent progress on the calculation of massive operator matrix elements (OMEs), which at three loop level receive contributions from Feynman diagrams containing two heavy quark

lines of different masses. These OMEs are needed in order to obtain the corresponding contributions for the massive Wilson coefficients in deep inelastic scattering at large momentum transfer. They are also needed to describe the variable flavor number scheme at three loops, where the charm and bottom quarks cannot be decoupled one at a time, since the ratio of the corresponding masses is not small enough. We show the full result for the two-mass non-singlet and pure singlet OMEs, and describe in detail the methods used to calculate the scalar Feynman integrals required to obtain the gluonic OMEs.

**Higgs physics and searches / 105**

## Higgs + jet production with full top mass dependence at two loops

**Corresponding Author:** [frellesvig@inp.demokritos.gr](mailto:frellesvig@inp.demokritos.gr)

The talk will be about the recent calculation of the planar Feynman integrals needed for the two-loop correction to Higgs-plus-jet production (arXiv:1609.06685) with full top-mass dependence, as well as the on-going work on the non-planar parts. I will discuss motivation, integral families, function classes, elliptic integrals, and more.

**Higgs physics and searches / 106**

## NLO matching for ttbb production with massive b-quarks

**Authors:** Jonas Lindert<sup>1</sup>; Niccolo Moretti<sup>None</sup>; Stefano Augusto Pozzorini<sup>2</sup>; Tomas Jezo<sup>3</sup>

<sup>1</sup> *IPPP Durham*

<sup>2</sup> *Universitaet Zuerich (CH)*

<sup>3</sup> *University of Zurich*

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Theoretical uncertainties in the simulation of ttbb production represent one of the main obstacles that still hamper the observation of Higgs-boson production in association with top-quark pairs in the  $H \rightarrow bb$ . We present a next-to-leading order (NLO) simulation ttbb production with massive b-quarks matched to Pythia within the POWHEG method with the hope of reconciling tension between previous calculations based on the MC@NLO method.

**Top, heavy quarks and searches / 107**

## A Study of the Top Mass Determination Using New NLO+PS generators

We estimate the top-quark mass extraction uncertainty due to Monte Carlo modeling of top-pair production and its leptonic decay. Using three different NLO+PS generators based on the POWHEG method implementing an increasingly precise treatment of tt production and decay, including hvq and bb4l, and two different PS implementations we obtain predictions for various kinematic distributions suitable for extraction of the top mass proposed in the literature. Assuming that one of the generators reproduces the data fully, we estimate the shift in the extracted top mass using the other generators. We find that the mass

shifts are comparable if not larger than the current experimental uncertainty on the top mass extraction.