

# Diffraction and Low-x 2018

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## Book of Abstracts



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## A model-independent method to extract $B(t)$ , $\rho(t)$ and the anomalous dimension of QCD from elastic pp scattering

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We present a new, model independent method that describes the differential cross-section of elastic pp scattering at LHC energies in a statistically acceptable manner. The results allow for a model independent determination of the momentum-transfer dependence of the slope parameter  $B(t)$  and the rho parameter  $\rho(t)$ , as well as for a new, non-perturbative determination of the anomalous dimension of QCD.

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## Combination and QCD analysis of beauty and charm production cross section measurements in deep inelastic ep scattering at HERA

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Measurements of open charm and beauty production cross sections in deep inelastic  $ep$  scattering at HERA from the H1 and ZEUS Collaborations are combined. Reduced cross sections are obtained in the kinematic range of negative four-momentum transfer squared of the photon  $2.5 \text{ GeV}^2 \leq Q^2 \leq 2000 \text{ GeV}^2$  and Bjorken scaling variable  $3 \cdot 10^{-5} \leq x_{Bj} \leq 5 \cdot 10^{-2}$ . The combination method accounts for the correlations of the statistical and systematic uncertainties among the different datasets. Perturbative QCD calculations are compared to the combined data. A next-to-leading order QCD analysis is performed using these data together with the combined inclusive deep inelastic scattering cross sections from HERA. The running charm- and beauty-quark masses are determined as  $m_c(m_c) = 1.290^{+0.046}_{-0.041}(\text{exp/fit})^{+0.062}_{-0.014}(\text{model})^{+0.003}_{-0.031}(\text{parameterisation}) \text{ GeV}$  and  $m_b(m_b) = 4.049^{+0.104}_{-0.109}(\text{exp/fit})^{+0.090}_{-0.032}(\text{model})^{+0.001}_{-0.031}(\text{parameterisation}) \text{ GeV}$ .

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## Crossing the bridge from BFKL to saturation.

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In hadron collisions, and especially heavy ion collisions, the parton density grows as a function of center of mass energy. At large center of mass energy, when relatively small transverse momentum is involved, this first leads to the perturbative resummation of large logarithms. The dominant contribution to this evolution is the BFKL Pomeron. As the center of mass energy continues to increase, parton densities grow, saturate, and the physics is determined by non-linear interactions. This is described by the BK-JIMWLK equation. By matching BFKL calculations to those done with TMDs and the CGC, we present progress on modeling the transitional behavior between the linear and non-linear high energy behavior of dijet processes.

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## Exclusive $\rho(770)$ photoproduction at HERA

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Exclusive photoproduction of  $\rho(770)$  vector mesons is studied using the H1 detector at HERA. A sample of about 700000 decays  $\rho \rightarrow \pi^+\pi^-$  was collected in the years 2006-2007, using the H1 fast track trigger. It corresponds to an integrated luminosity of  $1.3 \text{ pb}^{-1}$ . The sample is used to study cross-sections as a function of the invariant mass  $m_{\pi\pi}$  of the decay pions, the photon-proton collision energy  $W$  and the momentum transfer at the proton vertex  $t$ . The phase-space restrictions are  $0.5 < m_{\pi\pi} < 1.3 \text{ GeV}$ ,  $20 < W < 80 \text{ GeV}$  and  $|t| < 1.5 \text{ GeV}^2$ . Reactions where the proton stays intact are statistically separated from those where the proton dissociates to a low-mass hadronic system. The observed cross-section dependencies are parameterized using fits and are compared to expectations from phenomenological models.

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## Exclusive Photoproduction of $2\pi^+2\pi^-$ Final State at HERA

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Exclusive production of four charged pions at the ep collider HERA is studied at small photon virtualities  $Q^2 < 2 \text{ GeV}^2$ . The data were taken with the H1 detector in the years 2006 and 2007 at a centre-of-mass energy of  $\sqrt{s} = 319 \text{ GeV}$  and correspond to an integrated luminosity of  $7.6 \text{ pb}^{-1}$ . The cross section of the reaction  $\gamma p \rightarrow 2(\pi^+\pi^-)Y$  is determined in the phase space of  $45 < W_{\gamma p} < 100 \text{ GeV}$ ,  $|t| < 1 \text{ GeV}^2$  and  $M_Y < 1.6 \text{ GeV}$ . The  $4\pi$  mass spectra indicate that the reaction proceeds predominately via production and decay of  $\rho(1450)$  and  $\rho(1700)$  resonances. Parameters of these resonances as well as production cross sections times branching ratio into four charged pions are estimated from the mass fit, which includes contributions from non-resonant  $4\pi$  channel and interference terms.

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## GKG18 diffractive parton distribution functions and their uncertainties in the xFitter framework

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In this talk, we review the current status of global analyses in QCD of diffractive parton distribution functions (diffractive PDFs) and their uncertainties, focusing on very recent diffractive PDFs analysis of  $\{tt\text{ GKG18-DPDFs}\}$ , which is the first diffractive PDFs extracted from high-precision data from H1/ZEUS combined inclusive diffractive cross sections measurements.  $\{tt\text{ GKG18-DPDFs}\}$  is also the first global set of diffractive PDFs determined within the  $\{tt\text{ xFitter}\}$  framework. Heavy quark contributions in  $\{tt\text{ GKG18-DPDFs}\}$  analysis are considered within the framework of the ‘TR’ general mass variable flavor number scheme ( $\{tt\text{ GM-VFNS}\}$ ).

We also present and compared the most recent diffractive PDFs sets available, considering the latest improvements, the included data sets and the theoretical details and finally the next steps need to be made in the determination of diffractive PDFs.

Reference: Eur. Phys. J. C 78, no. 4, 309 (2018), arXiv:1802.01363 [hep-ph].

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## QCD analysis of the ATLAS and CMS W and Z cross-section measurements and implications for the strange sea density

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In the present paper, the ATLAS inclusive W and Z boson production data are analysed together with the CMS inclusive W and Z boson production data to investigate any possible tensions between the data sets and to determine the strange sea fraction, within the framework of a parton distribution function fit at next-to-next-to leading order in perturbative QCD.

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## Impact of low-x resummation on QCD analysis of HERA data

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Fits to the final combined HERA deep-inelastic scattering cross-section data within the conventional DGLAP framework of QCD have shown some tension at low x and low Q<sup>2</sup>. A resolution of this tension incorporating  $\ln(1/x)$ -resummation terms into the HERAPDF fits is investigated using the

xFitter program. The kinematic region where this resummation is important is delineated. Such high-energy resummation not only gives a better description of the data, particularly of the longitudinal structure function FL, it also results in a gluon PDF which is steeply rising at low x for low scales,  $Q^2 \ll 2.5 \text{ GeV}^2$ , contrary to the fixed-order NLO and NNLO gluon PDF.

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## A Model for Soft and Hard Interactions based on the CGC/Saturation Approach

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A model based on CGC/Saturation approach and the BFKL Pomeron was originally constructed to describe soft hadronic interactions at LHC energies [reference (a)]. It has now been extended to also describe hard interactions at HERA energies [reference (b)]. The model also describes inclusive production, rapidity and angular correlations over a wide range of energies. We outline the formalism and compare predictions with the relevant experimental data.

(a) Gotsman, Levin and Maor, Eur.Phys.J.C75, 179 (2015)

(b) Gotsman, Levin and Potashnikova, Phys.Lett.B781 (2018) 155.

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## Entropy production and its time evolution in High energy energy QCD

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Working in the framework of the Color Glass Condensate effective theory of high energy QCD, we investigate the momentum space entanglement entropy of the soft gluons produced in high energy dilute-dense collisions.

Entropy in the final state of a high energy collision arises due to decoherence of eigenstates with different energies during the time evolution after the collisions with the target. We define it rigorously as the entanglement entropy of the produced system with the experimental apparatus and we compute the time dependent single event entropy in the limit of weak projectile field.

Further we compute the entropy for the ensemble of events defined by the McLerran-Venugopalan model for the projectile wave function.

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## Searching for axion-like particles with proton tagging

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The existence of an axion-like particle (ALP) would induce anomalous scattering of light by light. This process can be probed at the Large Hadron Collider in central exclusive production of photon pairs in proton-proton collisions by tagging the surviving protons using proton spectrometers. We estimate the expected bounds on the ALP-photon coupling for a wide range of masses. We show that the proposed search is competitive and complementary to other collider bounds for masses above 600 GeV, especially for resonant ALP production between 600 GeV and 2 TeV.

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## Anomalous coupling studies at the LHC with intact protons

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We will describe the results on quartic anomalous coupling between photons, W, Z bosons at the LHC.

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## Effects of absorption in single-spin asymmetry of small-angle elastic scattering

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We investigate the single spin asymmetry,  $A_N(t)$ , arising from Coulomb-nuclear interference (CNI) in small-angle elastic scattering. Previous theoretical predictions failed to explain the nontrivial  $t$ -dependence of  $A_N$  in elastic proton-gold scattering, measured recently at RHIC.

We found that the absorptive corrections make the Coulomb amplitude of  $pA$  elastic scattering cause significantly different from  $eA$  scattering, leading dramatic effects in  $t$ -dependence. Trying to be more precise, we also included in the elastic proton-nucleus amplitude the corrections, related to Gribov inelastic shadowing and  $NN$  correlations.

Moreover, we demonstrate importance of the absorptive corrections also for the analysis of data on polarized  $pp$  elastic scattering, which previously revealed a zero spin-flip part of the Pomeron. The absorption corrected analyses leads to an essentially non-zero hadronic spin-flip.

This can be tested in the forthcoming measurements by the STAR experiment at 510 GeV.

Finally, we investigate the contribution to  $A_N$  from odderon-Pomeron interference.

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## Proton Spin in Deep Inelastic Scattering

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So far the analysis of the polarized structure functions have been limited to the evaluation of their integrals and comparing them to the prediction of the static quark model of the nucleon given by Ellis and Jaffe. We extended our analysis to the  $x$  dependence of the polarized structure functions and observe: the measured structure function excellently agrees with the prediction of the static quark model for Bjorken  $x > 0.1$  and drops rapidly for  $x < 0.1$ . It is suggested that for Bjorken  $x > 0.1$  electrons get scattered on the undamaged constituent quarks (alias valence quarks)–quasi elastic scattering on the constituent quarks–and for  $x < 0.1$  the constituent quarks fragment. In the fragmentation strong interaction is involved which does not preserve the polarization.

About 50\% of the constituent quarks survive the collision with electrons at  $Q^2 \sim 2 \text{ GeV}^2$  undamaged what implies that the constituent quark is a rather strongly bound rigid object. The polarization measurements of the quarks of the nucleon strongly supports the constituent quark as the step in the ladder between the sea quark and the nucleon. The low  $x$  physics is the only way to study the structure of the constituent quarks.

22

## Exclusive J/psi production in PbPb collisions at LHCb

**Author:** Katharina Mueller<sup>1</sup>

<sup>1</sup> *Universitaet Zuerich*

**Corresponding Author:** kmueller@physik.uzh.ch

At the LHC, the highly boosted electromagnetic field of the beam particles represents a source of quasi-real photon. Vector meson photo-production measurements in Pb-Pb collisions are sensitive to the gluon parton distribution functions in the nucleus. LHCb results on charmonium production in ultra-peripheral Pb-Pb collisions at 5.02 TeV will be presented.

23

## Central exclusive production at LHCb

**Author:** Katharina Mueller<sup>1</sup>

<sup>1</sup> *Universitaet Zuerich*

**Corresponding Author:** kmueller@physik.uzh.ch



The installation of scintillating pad detectors (Herschel), bracketing the LHCb detector along the beamline, have significantly enhanced LHCb's sensitivity to central exclusive production. Additionally, dedicated triggers during the early measurement period of Run 2 have produced an extended CEP dataset. A summary of results from Run 1 as well as early results from Run 2 will be shown.

24

## Soft QCD at LHCb

**Author:** Katharina Mueller<sup>1</sup>

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The forward acceptance of LHCb,  $2.0 < y < 5.0$ , provides a complementary reach to the general purpose detectors on LHC for studies of minimum bias properties. Recent measurements in this area at LHCb, including measurements of bose-einstein correlations, will be presented.

25

## Recent developments in Small- $x$ Resummation

**Author:** Marco Bonvini<sup>1</sup>

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I will discuss recent developments in the theory of small- $x$  resummation. These include the matching of resummation to fixed NNLO (and even N<sup>3</sup>LO), the construction of a variable flavour number scheme at small  $x$ , the resummation of the heavy-flavour matching conditions, a new formalism for the resummation of physical observables, and a variety of technical improvements. All these results have been implemented in a public code, HELL, which made possible the determination of PDFs with small- $x$  resummation, showing a significantly better agreement with HERA data at low  $x$ . The impact of resummation at present and future colliders will be discussed.

26

## Towards a Neural Network determination of nuclear parton distribution functions

**Authors:** Rabah Abdul Khalek<sup>1</sup>; Juan Rojo<sup>2</sup>

<sup>1</sup> *Nikhef*

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The QCD factorization theorems allows one to write any hard-scattering cross section involving hadrons in the initial state as a convolution between perturbative matrix elements and non-perturbative parton distributions functions (PDFs), which need to be extracted from experimental data by means of a global QCD analysis. Thanks to recent progress from both experiment and theory, the PDFs

of free nucleons are currently well known over a wide kinematic range. However, the situation is rather different for the case of bound nucleons inside heavy nuclei, where a number of effects lead to differences between the nuclear PDFs (nPDFs) and their free nucleon counterparts. Improving our understanding of nPDFs is of crucial importance for the modeling of the initial state in heavy ion collisions. In this talk I will present the progress towards a first determination of nPDFs based on the NNPDF framework, extensively used for the cases of unpolarised and polarised free nucleon PDFs.

27

## Particle multiplicities in the central region of high-energy collisions from $k_T$ -factorization with running coupling corrections

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Horowitz and Kovchegov have derived a  $k_T$ -factorization formula for particle production at small  $x$  which includes running coupling corrections. We perform a first numerical analysis to confront the theory with data on the energy and centrality dependence of particle multiplicities at midrapidity in high-energy p+A and A+A collisions. Moreover, we point out a strikingly different dependence of the multiplicity per participant on  $N_{\text{part}}$  in p+Pb vs. Pb+Pb collisions at LHC energies, and argue that the observed behavior follows rather naturally from the convolution of the gluon distributions of an asymmetric vs. symmetric projectile and target.

28

## Latest Results on MMHT PDF Fits

**Author:** Lucian Harland-Lang<sup>1</sup>

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

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The latest results within the MMHT global PDF fitting framework will be presented. Particular focus will be made on the issues related to fitting the most recent high precision LHC data, and work towards the next global PDF release. Other questions, such as the inclusion of the photon PDF within the MMHT framework and impact of theoretical uncertainties in PDF fits will be discussed.

29

## Superchic supercharged: an updated generator for exclusive production

**Author:** Lucian Harland-Lang<sup>1</sup>

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**Corresponding Author:** l.harland-lang@ucl.ac.uk

A new release of the SuperChic Monte Carlo event generator for central exclusive production (CEP) processes will be presented. Updates include: the addition of photon and QCD-induced production in heavy ion collisions (with a full treatment of absorptive effects); the addition of a range of new processes, such as the production of axion-like particles, electroweakly coupled SUSY states, monopoles and monopodium; an improved treatment of light-by-light scattering including W boson loops. A discussion of these improvements, and a range of phenomenological results, will be presented.

30

## Recent Elastic and Total Cross-Section Measurements by TOTEM

**Authors:** Mario Deile<sup>1</sup>; TOTEM Collaboration<sup>None</sup>

<sup>1</sup> *CERN*

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The TOTEM experiment at the interaction point 5 of the LHC has measured the total, elastic and inelastic proton-proton cross sections in a centre-of-mass energy range from 2.76 to 13 TeV, mostly in dedicated fills with special beam optics.

Most recently, TOTEM has performed a series of detailed measurements at  $\sqrt{s} = 13$  TeV. The total, elastic and inelastic proton-proton cross-sections were determined using the luminosity-independent method based on the optical theorem. Elastic scattering data in the Coulomb-nuclear interference region, at squared four-momentum transfers down to  $|t| \sim 8 \times 10^{-4} \text{ GeV}^2$  allowed the first measurement of the  $\rho$  parameter at  $\sqrt{s} = 13$  TeV, where  $\rho$  is the ratio between the real and the imaginary part of the nuclear elastic scattering amplitude at  $t = 0$ . This measurement, combined with the TOTEM total cross-section results, led to the exclusion of all the models classified and published by COMPETE. The  $\rho$  and  $\sigma_{tot}$  results obtained by TOTEM are compatible with predictions of a colourless 3-gluon bound state exchange in the t-channel of proton-proton elastic scattering, as postulated by alternative theoretical models both in the Regge-like framework and in the modern QCD framework.

On the large  $|t|$  side the elastic differential cross-section measurement was pushed to  $4 \text{ GeV}^2$ . Thanks to very high statistics, the dip-bump structure between  $0.4$  and  $0.8 \text{ GeV}^2$  was surveyed with unprecedented precision. At higher  $|t|$ -values up to the end of the observed range no further structure is present, and the data can be described with a power law.

The presentation will conclude with an outlook on planned future measurements.

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## Heavy Meson Coherent Photoproduction in (Ultra)-Peripheral AA Collisions

**Authors:** M.Beatriz Gay Ducati<sup>1</sup>; Sony Martins<sup>1</sup>

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An excess of  $J/\psi$  yield at very low transverse momentum ( $p_T < 0.3$  GeV/c) has been observed by the ALICE collaboration in peripheral collisions Pb-Pb at forward rapidity. It was also confirmed by the STAR collaboration in peripheral collisions Au-Au and U-U at mid-rapidity. Assuming the coherent photoproduction is the main mechanism behind this effect, the rapidity distribution and nuclear modification factor ( $R_{AA}$ ) were calculated for  $J/\psi$  and other heavy mesons ( $\psi(2S)$ ,  $Y(1S)$ ,  $Y(2S)$ ,  $Y(3S)$ ) for the LHC Run I ( $\sqrt{s} = 2.76$  TeV) and Run II ( $\sqrt{s} = 5.02$  TeV) energies. The results obtained were compared with the ALICE measurements. Similarly to the theoretical approach used in ultraperipheral collisions (UPCs), the cross section of the coherent photoproduction can be written as the convolution of a virtual photon flux created by the incoming nuclei with the photonuclear cross section that characterizes the photon-target interaction. In our analysis, two hypotheses are considered: (1) all the charges in the source and all the nucleons in the target contribute to the photonuclear cross section and (2) only the spectators in the target are the ones that interact coherently with the photon. In both hypotheses, an effective photon flux is built as function of the usual photon flux using a geometrical approach and results are compared with data.

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## Scaling function for the production of vector mesons and DVCS in the saturation scheme

**Authors:** Felipe Gregoletto Ben<sup>1</sup>; Magno Machado<sup>2</sup>; Werner Sauter<sup>3</sup>

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In this work, we discuss a universal expression for cross sections for the exclusive production of particles in scattering processes in the so-called saturation region. Within this scheme the phenomenon of geometric scaling takes place: cross sections are functions only of a dimensionless combination of the relevant kinematic variables, which happens both in inclusive and diffractive cases, as in the production of vector mesons. In particular, the scaling variable is given in general by  $\tau = Q^2/Q_s^2$ , where  $Q^2$  is the photon virtuality and  $Q_s$  represents the saturation scale, which drives the energy dependence and the corresponding nuclear effects.

This phenomenological result describes all available data from DESY-HERA for  $\rho$ ,  $\phi$  and  $J/\psi$  production and DVCS measurements. A discussion is also carried out on the size of nuclear shadowing corrections on photon-nucleus interaction. Some remarks are also carried on diffractive cross sections.

This work has been published in the following paper <https://journals.aps.org/prd/abstract/10.1103/PhysRevD.96.054015>

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## Recent CMS results on soft and small-x QCD physics

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

We present latest results of soft and small-x QCD measurements with the CMS experiment, such as minimum bias/underlying event physics, and studies on forward jet production.

34

## Recent CMS results on total inelastic, diffractive and exclusive measurements

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

We present latest results of diffractive and exclusive measurements with the CMS experiment, such as inelastic cross section measurements, diffractive jet production, measurements of exclusive epsilon and rho production, and studies of central exclusive production (CEP) processes.

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## Recent results from PPS and prospects

**Author:** CMS and TOTEM Collaborations<sup>None</sup>

We will describe recent results from PPS on exclusive dileptons and diphotons and prospects for future analyses.

36

## The PPS detector: status and performance

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

The PPS detector from CMS and TOTEM will be presented

37

## Nucleon spin structure from lattice QCD

**Author:** Kyriakos Hadjiyiannakou<sup>1</sup>

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We will present results on the spin and momentum decomposition among the quarks and gluons in the nucleon using state-of-the-art lattice QCD simulations.

Techniques for the accurate evaluation of sea-quark and gluon contributions at the physical pion mass will be discussed.

Challenges and perspectives for future developments will be presented.

38

## Jet production in pA and AA collisions in CMS

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

Recent jet results in pA and AA collisions will be presented.

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## Vector meson production and photon production in pA and AA collisions in CMS

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

Some new results on  $\Psi(2S)$ , D meson, di-photon productions from CMS will be presented.

40

## Leptoproduction of $\rho$ -mesons as discriminator for the unintegrated gluon distribution in the proton

**Authors:** Andr e Dafne Bolognino<sup>1</sup>; Francesco Giovanni Celiberto<sup>2</sup>; Dmitry Ivanov<sup>None</sup>; Alessandro Papa<sup>1</sup>

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The gluon content of the proton, in the high-energy regime, is embodied by the unintegrated gluon distribution (UGD), which describes the probability that a gluon can be emitted by a colliding proton, with a given longitudinal momentum fraction and transverse momentum.

The UGD, which is formulated within the  $k_T$ -factorization approach, has universal validity and several models for it have been proposed so far.

We will show that the polarized  $\rho$ -meson leptoproduction at HERA is a not trivial testfield for discriminating among existing models of UGD.

41

## Study of ordered hadron chains with the ATLAS detector

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

The analysis of the momentum difference between charged hadrons in high-energy proton-proton collisions is performed in order to study coherent particle production. The observed correlation pattern agrees with a model of a helical QCD string fragmenting into a chain of ground-state hadrons. A threshold momentum difference in the production of adjacent pairs of charged hadrons is observed, in agreement with model predictions. The presence of low-mass hadron chains also explains the emergence of charge-combination-dependent two-particle correlations commonly attributed to Bose-Einstein interference. The data sample consists of 190 inverse microbarns of minimum bias events collected with proton-proton collisions at a center-of-mass energy of 7 TeV in the early low-luminosity data taking with the ATLAS detector at the LHC.

42

## Measuring jet substructure observables at the ATLAS Experiment

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

Jet substructure observables have significantly extended the search program for physics beyond the Standard Model at the Large Hadron Collider. The state-of-the-art tools have been motivated by theoretical calculations, but there has never been a direct comparison between data and calculations of jet substructure observables that are accurate beyond leading-logarithm approximation. Such observables are significant not only for probing the collinear regime of QCD that is largely unexplored at a hadron collider, but also for improving the understanding of jet substructure properties that are used in many studies at the Large Hadron Collider. The ATLAS collaboration has recently performed several measurements of precision jet substructure at 13 TeV that will significantly extend our understanding of both the perturbative and non-perturbative aspects of jet formation. These measurements of jet mass in various topologies as well as other properties of jet fragmentation such as charged-particle multiplicity and the properties of gluon splitting to bottom quarks are unfolded to correct for detector effects and compared with a variety of predictions.

43

## Probing perturbative QCD at the ATLAS Experiment

**Author:** Speaker ATLAS<sup>1</sup>

<sup>1</sup> *ATLAS collaboration*

Perturbative QCD calculations at next-to-leading order are available for the jet production in pp collisions since several years and next-to-next-to leading order calculations also became available recently. In this talk, we present the latest results from the ATLAS collaboration for inclusive jets and dijets, measured at center of mass energies of 8 and 13 TeV. All measured cross-sections are compared to state-of-the-art theory predictions. Moreover, we present two measurements of dijet correlations allowing to test the renormalization group equation and to extract the strong coupling constant.

44

## Tests of Perturbative QCD with Photon Final States at the ATLAS Experiment

**Author:** Speaker ATLAS<sup>1</sup>

<sup>1</sup> *ATLAS*

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 numerous cross section measurements of prompt photon production, among which are a precise measurement of the production of isolated prompt photons in association with heavy flavor jets and a first measurement of the production cross-section of triphoton final states at a center of mass energy of 8 TeV, as well as a photon plus jet cross section measurement at 13 TeV. If available, a measurement of diphotons in association with jets and a ratio of photon cross sections between 8 and 13 TeV will also be presented. The results are compared with state-of-the-art theory predictions, indicating several interesting discrepancies.

45

## Measurements of elastic pp interactions and exclusive production with the ATLAS detector

**Author:** speaker ATLAS<sup>1</sup>

<sup>1</sup> ATLAS

The total pp cross section is a fundamental observable at the LHC. It can be derived from the measurement of the elastic cross section, using the optical theorem. Measurements of the elastic proton-proton cross section were performed at a center-of-mass energy of 8 TeV at various settings of the beam optics using the ALFA detector.

The ALFA detector is also used to tag forward protons in order to enrich the exclusive diffractive production of pion pairs for first cross section measurements of this process at center-of-mass energies of 7 and 8 TeV.

In the absence of forward proton tagging, exclusive processes can be distinguished in the central part of the ATLAS detector exploiting the absence of charged particles reconstructed in the inner tracking detector.

If available, the talk will also cover the study of the exclusive pion production at 7 and 8 TeV, the total cross section and rho determination from elastic scattering, as well as an inclusive single diffractive study at 8 TeV.

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## Constraints on the Parton Density Functions of the Proton by Measurements with the ATLAS Detector

**Author:** Collaboration Atlas<sup>1</sup>

<sup>1</sup> ATLAS

Parton distribution functions (PDFs) are crucial ingredients for measurements at hadron colliders, since they describe the initial states and therefore critically impact the precision of cross section predictions for observables. This talk will review recent precision analyses, where the PDFs play an important role and discuss the impact of several new ATLAS cross-section measurements on PDFs of the proton.

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## New Results on the W Boson Production and Multi-lepton Cross Sections with the ATLAS Detector

**Author:** Speaker ATLAS<sup>1</sup>

<sup>1</sup> ATLAS

We report on the latest measurement on the production of W bosons in association with jets at 8 TeV and compare our results to the latest theoretical predictions. Differential cross sections for events with one or two jets are presented for a range of observables, including jet transverse momenta and rapidities, the scalar sum of transverse momenta of the visible particles in the event, and the transverse momentum of the W boson. For a subset of the observables, the differential cross sections of positively and negatively charged W bosons are measured separately.

Moreover, the exclusive muon pair production measurement at 13 TeV is presented and the results are compared to theoretical predictions. The integrated cross-section is determined within a fiducial



acceptance region of the ATLAS detector and differential cross-sections are measured as a function of the dimuon invariant mass. If available, a study of the W and Z boson production in association with 1 or 2 b-jets will be presented.

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## New Results on Z Boson Production with the ATLAS Detector

**Author:** speaker ATLAS<sup>1</sup>

<sup>1</sup> ATLAS

Precision measurements of the Drell-Yan production of Z bosons at the LHC provide a benchmark of our understanding of perturbative QCD and electroweak processes and probe the proton structure in a unique way. ATLAS performed a precise triple differential Drell-Yan cross-section measurement as a function of  $M_{ll}$ , dilepton rapidity and  $\cos\theta^*$  defined in the Collins-Soper frame at a center of mass energy of 8 TeV. We report on this measurement which provides sensitivity to PDFs and the Z forward-backward asymmetry, AFB. In order to test the electroweak sector with single Z boson final states, ATLAS has published a first measurement of the tau-polarization in Z events as well as the cross-section of the electroweak production of Z bosons at 13 TeV. These results will be presented and discussed.

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## Tests of the electroweak sector with Diboson final states at the ATLAS Experiment

**Author:** speaker ATLAS<sup>1</sup>

<sup>1</sup> ATLAS

Measurements of the cross sections of the production of pairs of electroweak gauge bosons at the LHC constitute stringent tests of the electroweak sector and provide model-independent means to search for new physics at the TeV scale. Similarly, the electroweak production of vector bosons in proton-proton collisions tests the gauge structure of the Standard Model. The ATLAS collaboration has performed detailed measurements of integrated and differential cross sections of the production of ZZ di-boson pairs as well as WZ and WW di-boson pairs at 8 and 13 TeV. The results will be presented and compared to predictions at NLO (and NNLO) in pQCD. Constraints on new physics are provided by setting limits on anomalous triple gauge couplings. If available, a measurement of the unfolded 4-lepton mass at 13 TeV will be presented.

50

## New Results on Multi-Boson Production with the ATLAS Detector

**Author:** speaker ATLAS<sup>1</sup>

<sup>1</sup> ATLAS

Measurements of the cross sections of the production of three electroweak gauge bosons and of vector-boson scattering processes 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 searched 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. ATLAS also searches for the electroweak production of diboson final states, where evidence was found for the exclusive production of W boson pairs. If available also further results on the electroweak production of diboson pairs will be presented. All results have been used to constrain anomalous gauge couplings and have been compared to the latest theory predictions.

51

## Inclusive hadron-jet production at the LHC

**Authors:** Andr e Dafne Bolognino<sup>1</sup>; Francesco Giovanni Celiberto<sup>2</sup>; Mohammed Maher Abdelrahim Mohammed<sup>3</sup>; Dmitry Ivanov<sup>None</sup>; Alessandro Papa<sup>1</sup>

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The inclusive production at the LHC of a charged light hadron and of a jet, featuring a wide separation in rapidity, is suggested as a new probe process for the investigation of the BFKL mechanism of resummation of energy logarithms in the QCD perturbative series. We present some predictions, tailored on the CMS and CASTOR acceptances, for the cross section averaged over the azimuthal angle between the identified jet and hadron and for azimuthal correlations.

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## Multi particle production in proton-nucleus collisions

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Using the formalism of the light-cone wave function in perturbative QCD together with the hybrid factorization, we compute the cross-section for three particle production at forward rapidities in proton-nucleus collisions. In this picture, the three produced partons – a quark accompanied by a gluon pair, or two quarks plus one antiquark – are all generated via one or two successive splittings of a quark from the incoming proton, that was originally collinear with the latter. The three partons are put on-shell by their scattering off the nuclear target, described as Lorentz-contracted shockwave. We explicitly compute the three-parton Fock space components of the light-cone wave function of the incoming quark and also the outgoing state, which encodes the information on the scattering process. This outgoing state is also an ingredient for other interesting calculations, like the next-to-leading order correction to the cross-section for the production of a pair of jets.

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## Heavy quarkonium and dynamical gluon mass at non-zero temperature in instanton vacuum model

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Heavy quarkonium  $Q\bar{Q}$  states created (together with hot hadron/quark-gluon matter) in high energy hadron-hadron/ion-ion collisions can be used as a thermometer. This is one of the motivation to study the heavy quarks dynamics in a broad range of temperatures  $T$ . On the other hand, not only light but also heavy quarks physics is sensitive to one of the properties of QCD vacuum – instantons.

In the present talk we discuss various applications of the instanton liquid model (ILM) at non-zero  $T$ :

1. Different scenarios for the  $T$ -dependence of the mean instanton size  $\bar{\rho}(T)$  and density  $n(T)$ .
2. Direct contribution of the instantons to the central  $Q\bar{Q}$  potential, which might be essential at the distances of the order of the mean instanton size  $\bar{\rho}(T)$ .
3. Modification of the gluon properties in ILM, affects the perturbative one-gluon exchange contribution, important for the  $Q\bar{Q}$  potential. We found that in ILM the gluons acquire a dynamical "electric" gluon mass  $M_{el}(q, T)$ , which depends on temperature. At typical  $\bar{\rho}(0) = 1/3$  fm and  $n(0) = 1$  fm<sup>-4</sup> gluons acquire mass  $M_{el}(0, 0) \approx 362$  MeV, which decreases with  $T$ . The  $T$ -dependence of the mass strongly correlates with the temperature dependence of the instanton vacuum parameters  $\bar{\rho}(T)$ ,  $n(T)$ . The inclusion of one-loop thermal gluon corrections leads to a rising with temperature contribution  $M_{pert,el}(0, T) \sim T$  and allows to reproduce the lattice results for the dynamical gluon mass.

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## Recent results on Central Exclusive Production with the STAR detector at RHIC

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The STAR experiment at the Relativistic Heavy Ion Collider (RHIC) performs studies of diffractive processes with the focus on the exclusive production of particles in central range of rapidity. In 2015 STAR collected 18 pb<sup>-1</sup> of data in polarized proton-proton collisions at  $\sqrt{s} = 200$  GeV to measure Central Exclusive Production (CEP) process  $pp \rightarrow pXp$  through Double Pomeron Exchange (DPE) mechanism, which is expected to be dominant at this center-of-mass energy.

The intact protons moving inside the RHIC beam pipe after the collision were measured in Roman Pot detectors. The CEP events were identified using transverse momentum balance of the central diffractive system measured in the Time Projection Chamber (TPC) and of the forward protons measured in the Roman Pots. With the use of ionization energy loss in the TPC,  $dE/dx$ , as well as velocity measured with the Time-Of-Flight detector (TOF), it was possible to identify various production channels in  $pp \rightarrow pXp$  reaction.

We shall present preliminary results on exclusive production of two opposite-charge particles ( $\pi^+\pi^-$ ,  $K^+K^-$ ,  $p\bar{p}$ ) in midrapidity region with small squared four-momentum transfer of forward protons,  $0.03 < |t_1|, |t_2| < 0.2$  (GeV/c)<sup>2</sup>.

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## Diffractive dijets: breakdown of factorization

**Authors:** Boris Kopeliovich<sup>1</sup>; Roman Pasechnik<sup>2</sup>; Irina Potashnikova<sup>3</sup>

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Data on diffractive dijet production reveal a dramatic failure of predictions based on diffractive factorization. The main source of factorization breaking is a principal difference between the mechanisms of diagonal diffraction in DIS and off-diagonal diffractive hadronic collisions. Single-diffractive excitation of two high-pT back-to-back jets is calculated within the dipole approach. The dominant mechanism of this diffractive process is semihard - semisoft, differently from dijet production in DIS, which is hard dominated. Results of calculation are in a good accord with data.

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## Measurements of particle spectra in diffractive p+p collisions with the STAR detector at RHIC

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We present the results of the diffractive measurement with the STAR Roman Pot detectors at RHIC. The measurement is focused on the spectra of identified charged particles as pions, kaons, protons and their antiparticle counterparts in Single Diffraction Dissociation ( $p + p \rightarrow p + X$ ) and Central Diffraction ( $p + p \rightarrow p + X + p$ ) processes. The spectra of inclusive charged particles are also measured.

The forward-scattered proton(s) were tagged in the STAR Roman Pot system while the charged particle tracks were reconstructed in the STAR Time Projection Chamber (TPC).

Ionization energy loss and time of flight of charged particles were used for particle identification. Moreover, the proton-antiproton production asymmetry as a function of rapidity is presented and allows one to study the baryon number transfer over a large space in rapidity in single diffraction. A similar effect has been studied in proton-proton and proton-photon interactions. In this talk we present the baryon number transfer in proton-Pomeron interactions.

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## Universal suppression in production of different high-pT hadrons in heavy ion collisions

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The recent ALICE data clearly demonstrate the universality of suppression of different high-pT hadrons containing light quarks produced inclusively in heavy ion collisions at Large Hadron Collider (LHC). Moreover, the last ATLAS results on production of prompt charmonia show almost the same attenuation as is observed in production of light hadrons. This fact leads naturally to a conclusion about an absence of a direct interplay between the parton energy loss in the medium and the particle species composition within the quenched jet. For this reason, such the universality cannot be predicted by models based on energy loss scenario and consequently on a long production length since different medium-induced radiation expected especially in production of light and heavy mesons and baryons should lead naturally to a different suppression. Within our non-energy loss interpretation of the jet quenching as a consequence of a short production length we can conclude that the main reason for suppression of high-pT hadrons in heavy ion collisions is controlled by the color transparency attenuation of high-pT dipoles propagating through the hot and dense medium. Using the same single parameter, the maximal value of the transport coefficient, adjusted in our previous studies of high-pT hadron production in the LHC kinematic region, we predict a similar suppression for inclusive high-pT production of pions, kaons, protons and charmonia calculating the nuclear attenuation factor  $R_{\{AA\}}$  as function of pT and centrality in a good agreement with available LHC data.

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## Measurement of Total and Elastic Cross Sections at $\sqrt{s} = 200$ GeV with the STAR Detector at RHIC

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We present results of the measurement of the total and elastic cross sections in proton–proton collisions at  $\sqrt{s} = 200$  GeV with the Roman Pot setup in Run 2015 of the STAR experiment at the Relativistic Heavy Ion Collider (RHIC). The Roman Pots were operated during standard data collection at STAR at the distance of about  $8\sigma_y$  from the beam, where  $\sigma_y$  is the beam gaussian width in the vertical coordinate. The obtained data sample is in the useful range of the square of four–momentum transfer ( $t$ )  $0.05 \leq -t \leq 0.135$  (GeV/c)<sup>2</sup>. The results include the value of the exponential slope parameter  $B$  of the elastic differential cross section  $d\sigma/dt$  in the measured small  $-t$  range and the total cross section  $\sigma_{tot}$  obtained from the extrapolation of the  $d\sigma/dt$  to the optical point at  $-t = 0$  (GeV/c)<sup>2</sup>. We also present the value of elastic cross section  $\sigma_{el}$ . All results are compared with the world data.

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## New physics from TOTEM’s recent measurements of elastic and total cross sections

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By using a Regge-pole model, including pomeron and odderon exchanges as double poles we analyze the recently discovered phenomena in elastic proton-proton scattering at the LHC: the low- $|t|$  “break” (departure from the exponential behavior of the diffraction cone), the accelerating rise with energy

of the forward slope  $B(s)$ , the absence of secondary dips and bumps on the cone and the unexpected decrease of the ratio of the real to imaginary part of the forward amplitude at 13 TeV. The odderon may manifest in filling the dip at 13 TeV.

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## The odderon: myths and reality

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The existence of the odderon, odd C-parity counterpart of the pomeron, was never questioned seriously simply because there is no constraint (“selection rule”) forbidding its existence. We discuss open questions concerning constraints imposed on the odderon by analyticity and unitarity, explicit parameterizations as well as possible manifestation of the odderon in experiment.

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## Single-Spin Asymmetry Measurement of Very Forward Neutral Particle Production in the RHICf experiment

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We installed an electro-magnetic calorimeter in the most forward area of the STAR experiment and took 510 GeV polarized proton collision data for neutral particle production (neutron, photon, neutral pion) at pseudorapidity  $> 6$ . The cross section measurement will give us new inputs to develop high-energy collision models which is essential to understand air-shower from ultra-high energy cosmic rays. The asymmetry measurement will enable us to understand the hadron collision mechanism based on QCD. The data were taken in June of 2017 with three detector positions in order to cover wide kinematic regions. STAR detector data were also recorded for combined data analysis. We will present evaluation of the experimental data and status of the asymmetry data analysis.

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## Diffraction electron-nucleus scattering and ancestry in branching random walks

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We point out an analogy between diffractive electron-nucleus scattering events, and realizations of one-dimensional branching random walks selected according to the height of the genealogical tree of the particles near their boundaries. This correspondence is made transparent in an event-by-event picture of diffraction emphasizing the statistical properties of gluon evolution, from which new

quantitative predictions straightforwardly follow: We are able to determine the distribution of the total invariant mass produced diffractively, which is an interesting observable that can potentially be measured at a future electron-ion collider.

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## Twist-2 transverse momentum distributions at NNLO in QCD

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The factorization theorem for DY and semi-inclusive DIS holds for all leading twist transverse momentum distributions. However a QCD perturbative calculation shows several important characteristics of spin-dependent distributions. We consider all the different spin-dependent distributions which can be matched onto integrated twist-2 functions, focusing on the transversity and pretzelosity distributions. The pretzelosity case is specially relevant because, using a direct perturbative calculation at one loop, we obtain a null result which agrees with the experimental measurements. We show the complete set results of the matching at NLO and the results focusing on transversity and pretzelosity at NNLO.

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## Probing gluon TMDs in $J/\psi$ and $\Upsilon$ production at an EIC

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Transverse-momentum dependent parton distribution functions (TMD PDFs, or TMDs for short), are fundamental objects in QCD which describe the parton content of a proton as a function of the parton's longitudinal momentum fraction  $x$  w.r.t. the proton, and its transverse momentum  $k_t$ . As such, they provide insight in the three-dimensional structure of the proton in terms of quarks and gluons. In recent years, considerable effort has been devoted to the study of gluon TMDs, which are experimentally less known than their quark counterparts.

In this work, we propose to probe gluon TMDs in the deep-inelastic scattering processes  $e + p \rightarrow [Q\bar{Q}] + X$  and  $e + p^\uparrow \rightarrow [Q\bar{Q}] + X$ , with  $[Q\bar{Q}]$  being either the  $J/\psi$  or  $\Upsilon$  heavy quarkonium states. The cross sections for these processes are computed in the TMD framework together with nonrelativistic QCD (NRQCD): an effective theory which allows to factorize the perturbatively calculable heavy-quark pair production from its subsequent nonperturbative hadronization into the quarkonium, which is encoded in so-called long-distance matrix elements (LDMEs). In the kinematical regime in which our TMD formalism is valid, the color octet (CO) production mechanism is expected to be dominant, where the heavy-quark pair is produced in a color state, and only during the hadronization decays to a singlet. The corresponding LDMEs are taken from fits to data from the LHC, RHIC, and TEVATRON, and are the largest source of uncertainty in our work. We show that the cross sections depend on five different gluon TMDs in total, each corresponding to a specific

azimuthal modulation which can be used to disentangle them, for instance from measurements at a future Electron-Ion Collider (EIC).

Gluon TMDs are of particular importance in the small- $x$  regime of QCD, which is characterized by such a high gluon density that nonlinear saturation effects are expected to become important. The small- $x$  dynamics of QCD is described by the Color Glass Condensate effective theory (CGC), which allows to calculate the nonlinear evolution of the gluon density in  $x$ , given a certain initial condition. In particular, the two gluon TMDs of the unpolarized proton, corresponding to unpolarized and linearly polarized gluons, respectively, can be calculated analytically in the nonperturbative McLerran-Venugopalan (MV) model for the gluon distribution at low- $x$ . Moreover, using a numerical implementation of the JIMWLK equation, their nonlinear evolution in  $x$  can be computed. With these results at hand, we show predictions for the  $\cos(2\phi_T)$  asymmetry in the  $e + p \rightarrow [Q\bar{Q}] + X$  cross section, which scales with the ratio of these two TMDs.

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## Possible solution of J/psi polarization puzzle in the CGC+NRQCD approach

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Studies of heavy quarkonia production in the hadronic collisions are a very good tool for testing various aspects of QCD. Despite many theoretical attempts, the long-standing problem of J/psi's polarization has resisted solution. We present our recent study on the J/psi polarization observables  $\lambda$ 's in a Color Glass Condensate (CGC) + Nonrelativistic QCQ (NRQCD) approach. Comparisons with LHCb and ALICE data on J/Psi are shown that indicate quite good agreement with the data – further test of this approach in high multiplicity proton-proton and proton-nucleus collisions are discussed.

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## Polarization observables in $\chi_c$ to J/psi+mu+mu Dalitz decays at the LHC

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Polarization observables play prominent role in modern physics and can provide unique and crucial information on the interaction dynamics. Our present note is devoted to a theoretical analysis of the decays of  $\chi_{c1}$  and  $\chi_{c2}$  mesons produced in high energy hadronic collisions:

$$pp \rightarrow \chi_{cJ} + X; \chi_{cJ} \rightarrow J/\psi + l^+l^-; J/\psi \rightarrow l^+l^-.$$

This study was inspired by a distinctive identification of  $\chi_{c1}$  and  $\chi_{c1}$  Dalitz decays at the LHCb collaboration at CERN.

In the context of  $\chi_{cJ}$  Dalitz decays, we consider three sets of polarization observables. First, is the polarization of the original  $\chi_{cJ}$  mesons that can be seen in the angular distributions of the resulting  $J/\psi$  mesons and virtual photons. Second, is the polarization of the daughter  $J/\psi$ 's that manifests



in the angular distributions of the decay leptons. Third, is the polarization of the virtual photon that can be seen in the angular distributions of the other lepton pair.

Our calculations are performed in the  $k_t$ -factorization approach and rely on the standard QCD perturbation theory and nonrelativistic bound state formalism. The Leading Order contribution is represented by a  $2 \rightarrow 1$  gluon-gluon fusion partonic subprocess  $g^* + g^* \rightarrow \chi_{cJ}$ ,  $J = 0, 1, 2$ , where the initial gluons are off-shell, have nonzero transverse momentum and nonzero longitudinal component in their polarization vector. The subsequent decays of  $\chi_{cJ}$  mesons are assumed to be dominated by electric dipole (E1) transitions.

We make numerical predictions for ‘helicity’ and Collins-Soper frames. We find that the polarization of  $\chi_{cJ}$  and  $J/\psi$  mesons is large and possesses nontrivial behavior as a function of  $\chi_{cJ}$  transverse momentum. Our predictions provide the necessary theoretical grounds for a comparison with forthcoming experiments.

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## Measurement of the exclusive $\gamma\gamma \rightarrow \mu^+\mu^-$ process in proton–proton collisions at $\sqrt{s}=13$ TeV with the ATLAS detector

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

The production of exclusive  $\gamma\gamma \rightarrow \mu^+\mu^-$  events in proton–proton collisions at a centre-of-mass energy of 13 TeV is measured with the ATLAS detector at the LHC, using data corresponding to an integrated luminosity of  $3.2 \text{ fb}^{-1}$ . The measurement is performed for a dimuon invariant mass of  $12 \text{ GeV} < m_{\mu^+\mu^-} < 70 \text{ GeV}$ . The integrated cross-section is determined within a fiducial acceptance region of the ATLAS detector and differential cross-sections are measured as a function of the dimuon invariant mass. The results are compared to theoretical predictions that include corrections for absorptive effects.

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## Latest results of diffractive and exclusive measurements with CMS

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

We present latest results of diffractive and exclusive measurements with the CMS experiment, such as measurements of exclusive  $\rho$  and  $\rho_0$  production, and studies of central exclusive production (CEP) processes. Exclusive  $\rho_0$  meson photoproduction in ultra-peripheral pPb collisions at  $\sqrt{s_{NN}} = 5.02 \text{ TeV}$  is studied, for the first time, at the LHC with the CMS Collaboration. The cross sections are measured as a function of the photon-proton centre-of-mass energy, extending the energy range explored by the H1 and ZEUS Collaboration at HERA. In addition, the differential cross sections ( $d\sigma/d|t|$ ), where  $|t| \approx p_T^2$  is the squared transverse momentum of produced vector mesons, are measured and the slope parameters are obtained. The results are compared to previous measurements and to theoretical predictions.

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## Forward Drell-Yan plus jet production as a probe of the BFKL dynamics

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We propose a new process which probes the BFKL dynamics in the high energy proton-proton scattering, namely the forward Drell-Yan production accompanied by a forward jet, separated from the DY lepton pair by a large rapidity interval.

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## Effects of saturation in high-multiplicity pp collisions

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Parton distributions in the protons colliding with multiplicity much higher than the mean value, are biased to higher parton densities, leading to enhanced effects of saturation. This and the effect of mutual boosting of the saturation scale significantly increase the gluon density at small  $x$ , and correspondingly the production rate of  $J/\psi$  and  $p_T$  broadening, in good accord with data.

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## Rapidity gap survival factors caused by remnant fragmentation for central electromagnetic production of $W^+W^-$

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We discuss production of  $W^+W^-$  pairs in proton-proton collisions induced by two-photon fusion including, for a first time, transverse momenta of incoming photons. The unintegrated inelastic fluxes (related to proton dissociation) of photons are calculated based on modern parametrizations of deep inelastic structure functions in a broad range of their arguments ( $x$  and  $Q^2$ ). In our approach we can get separate contributions of different  $W$  helicities states. We focus on processes with single and double proton dissociation. The hadronisation of proton remnants is performed with Pythia string fragmentation model, assuming a simple quark-diquark model for proton. Highly excited remnant systems hadronise producing particles that can be vetoed in the calorimeter. We calculate associated effective gap survival factors. The gap survival factors depend on the process, mass of the remnant system and collision energy. The rapidity gap survival factor due to remnant fragmentation for double dissociative (DD) collisions (SR,DD) is smaller than that for single dissociative (SD) process (SR,SD). We observe approximate factorisation:  $SR,DD \approx (SR,SD)^2$ , when imposing rapidity veto.

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72

## Vector meson photoproduction: Recent results

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In this contribution I review the recent progress in description of the vector meson photoproduction in hadronic colliders. In particular, I discuss the distinct treatments for the vector meson wave function, the contribution of the next - to - leading order corrections and the different models for the dipole - target scattering amplitude. Predictions for the light and heavy photoproduction in  $pp/pA/AA$  collisions at the run 2 LHC energies are presented.

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## Fluctuations in dilute systems

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We propose to review the main features of event-by-event gluon number fluctuations in the Fock states of onia (as models for dilute hadrons), as well as their observable consequences. We show that these fluctuations are quite different in nature depending on the very process, and on the energy range considered.

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## Toward Mueller-Tang Jets at Next-to-Leading Order

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In the search for a clear signal of underlying BFKL dynamics in high-energy diffractive processes the Mueller-Tang jet observables have been proven to be a particularly fortunate choice. Mueller-Tang jet processes are dijet events with no radiation recorded in the rapidity region between the jets.

Despite unperturbative effects that can affect the rapidity gap signature a color-singlet excess was observed and a fair agreement was found between the BFKL predictions and the Tevatron data.

The extent of the agreement was partially unexpected considering the modest energy available and the incomplete refinement of the BFKL predictions.

However, no conclusive connection between the observed excess and the BFKL predictions could be drawn. %of the observed rapidity gap with a BFKL single exchange

Recently, CMS published the first analysis for M-T jets at 7 TeV and the analysis for the 13 TeV run is underway. Thus, the BFKL domain is within reach of the current experiments and a great deal of interest is pointed toward the color-singlet processes.

On the other hand, the theoretical analysis must be extended to complete the BFKL next-to-leading order. In particular, important contributions are expected to stem from the recently calculated NLO corrections to the jet vertex, which have never been included in a phenomenology analysis before.

The inclusion of the NLO vertex passes through the implementation of the momentum space BFKL eigenfunctions, which represents a novelty in this context, and introduces several technical complications that hinder the theoretical analysis.

We present progresses toward this goal, explaining the origin of such complications and the chosen solutions.

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## On double pomeron exchange in J/psi hadroproduction

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Inclusive heavy vector meson hadroproduction is a subject of vivid experimental studies at the Large Hadron Collider. We consider in detail a new color singlet contribution to the J/psi production at the LHC, that is driven by a double BFKL pomeron exchange between the produced meson and a target parton. This production mechanism is closely related to a small x evolution of double gluon density including parton correlations. We estimate the differential cross sections and discuss their properties and relevance.

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## Algorithmics of Diffraction

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New analysis and synthesis approaches are introduced for high energy diffraction, especially for central exclusive processes at the LHC. The synthesis features include differential screening, an expendable set of process amplitudes with adaptive Monte Carlo sampling, spin systematics and a generator framework using modern computational techniques. For the analysis of inclusive events,

a systematic description of observables of diffraction is obtained by a fusion of incidence algebras and probability calculus.

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## light by light scattering in heavy ions collisions with the ATLAS detector

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

Light-by-light scattering ( $\gamma\gamma\rightarrow\gamma\gamma$ ) is a quantum-mechanical process that is forbidden in the classical theory of electrodynamics. This reaction is accessible at the Large Hadron Collider thanks to the large electromagnetic field strengths generated by ultra-relativistic colliding lead (Pb) ions. Using  $480\ \mu\text{b}^{-1}$  of Pb+Pb collision data recorded at a centre-of-mass energy per nucleon pair of 5.02 TeV by the ATLAS detector, the ATLAS Collaboration reports evidence for the  $\gamma\gamma\rightarrow\gamma\gamma$  reaction. A total of 13 candidate events are observed with an expected background of  $2.6\pm 0.7$  events. After background subtraction and analysis corrections, the fiducial cross section of the process  $\text{Pb}+\text{Pb}(\gamma\gamma)\rightarrow\text{Pb}^{(*)}+\text{Pb}^{(*)}\gamma\gamma$ , for photon transverse energy  $E_T>3$  GeV, photon absolute pseudorapidity  $|\eta|<2.4$ , diphoton invariant mass greater than 6 GeV, diphoton transverse momentum lower than 2 GeV and diphoton acoplanarity below 0.01, is measured to be  $70 \pm 24$  (stat.)  $\pm 17$  (syst.) nb, which is in agreement with Standard Model predictions.

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## Collective effects in DIS at HERA

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Collective effects in DIS at HERA

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## b production via a double muon tag

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b production via a double muon tag

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## Fits to high-x data and measurement of charm production in charged current

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Fits to high-x data and measurement of charm production in charged current

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## Probing Generalized Parton Distributions through the photoproduction of a photon-meson pair

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Exclusive photoproduction of a gamma-meson pair in the kinematics where the pair has a large invariant mass and the final nucleon has a small transverse momentum is described in the collinear factorization framework. The scattering amplitude is calculated at leading order in  $\alpha_S$  and the differential cross sections for the process are estimated in the kinematics of the JLab 12-GeV experiments.

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## Exclusive central production of the Pomeron tensor state in high-energy collisions of protons

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A simple model based on Regge approach is proposed for description of the exclusive central production of the light tensor glueball associated with the soft Pomeron Regge trajectory.

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## From BFKL to the soft Pomeron - an attempt to find an interpolation

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I report on a project which aims at understanding the connection between pQCD and the soft Pomeron. Recent new results include the formulation of the BFKL Pomeron in the framework of the Exact Renormalization Group, as well as and numerical results on the energy spectrum of the BFKL equation with an infrared cutoff.

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## Vector meson electro-production within the energy-dependent hot-spot model

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We will present a model in which we treat electro-production of light and heavy vector mesons using the color dipole approach including the quantum fluctuations of the target structure. These fluctuations are generated by hot spots, randomly placed in the transverse plane. The number of hot spots grows with decreasing Bjorken-x, which brings energy dependence of the target structure into this model. Our model successfully reproduces the exclusive and dissociative vector meson photo-production data from H1 and ALICE. Moreover, it predicts that once the proton structure starts to resemble the gluon saturation picture the dissociative cross section reaches a maximum and then decreases steeply with energy. We will show, that this signal is present also in electro-production cross section and it has clear mass and scale dependence measurable at LHeC energies.

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## The Odderon and the LHC data

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Analysis of the new experimental data obtained by the TOTEM Collaborations at LHC at  $\sqrt{s} = 13$  TeV at small momentum transfer is presented in the framework of the simplest form of the hadron scattering amplitude. The impact of the different assumptions on the extraction of the parameters of the elastic scattering amplitude, especially on the size of the  $\rho(t = 0)$ , is examined. The possible systematic and model dependent uncertainties in the obtained value of  $\rho(t = 0)$  are evaluated. The possible form and energy dependence of the Odderon contribution in the hadron scattering amplitude is examined in the framework of the High Energy Generalize Structure (HEGS) model. It is shown that the contribution of the maximal Odderon amplitude at  $t = 0$  is very small and a little impact on the size of  $\rho(t = 0)$ . However in the position of the diffraction minimum its impact can be non-negligible.

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## Exclusive vector meson production in the QCD shockwave approach.

**Authors:** Andrey Grabovsky<sup>1</sup>; Dmitry Ivanov<sup>None</sup>; Lech Szymanowski<sup>2</sup>; Renaud Boussarie<sup>3</sup>; Samuel Wallon<sup>None</sup>

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We present NLO calculation of the virtual photon to light vector meson impact factor in the QCD shock wave approach. This paves the way to the quantitative study of high-energy nucleon and nucleus saturation beyond the leading order.

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## Photon-Photon scattering in the resonance region at midrapidity at the LHC

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A study is presented to extend the measurements of photon-photon scattering in ultra-peripheral Pb-Pb collisions at the LHC into the mass region of the pseudoscalar resonances  $\eta$  and  $\eta'$ .

The elementary photon-photon scattering cross section discussed in Ref.1 is extended to the low masses of these pseudoscalars. The main background to two-photon final states, arising from double  $\pi^0$  production with two of the four decay photons escaping detection, is examined, and possible kinematical conditions are discussed to optimize the signal-to-background ratio for such measurements at mid-rapidity.

Ref.1:

M. Klusek-Gawenda, P. Lebedowicz, A. Szczurek, Phys.Rev.C93 (2016) no.4, 044907.

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## Amplitudes in the Multi-Regge Limit of N=4 SYM

**Author:** Bram Verbeek<sup>1</sup>

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**Corresponding Author:** bram.verbeek@uclouvain.be

A novel way of computing high-order amplitudes in the multi-Regge limit of planar maximally supersymmetric Yang-Mills theory is presented. In this framework, we are able to obtain high-loop and high-leg results by an easy operation on known lower-loop and lower-leg amplitudes. This mechanism will be reviewed, along with an ensuing factorisation which allows us to determine leading logarithmic MHV results for any number of legs at a fixed loop order.

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## NNLLA BFKL and Regge cuts

**Author:** Victor Fadin<sup>1</sup>

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The derivation of the BFKL equation based on the unitarity relations is strongly complicated in the next-to-next-to-leading logarithmic approximation. The main reason of the complication is appearance of Regge cuts in amplitudes with gluon quantum numbers in the cross channels and negative signature.

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## Forward physics results and perspectives with ALICE at the LHC

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

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The ALICE experiment is equipped with a broad range of detectors which allows one to study photon-induced and diffractive processes characterized by large rapidity gaps. The forward detectors of ALICE are used to detect rapidity gaps and to trigger on diffraction events. Special attention is given to double gap events, dominated by central-exclusive processes, because of the high-performance tracking and particle identification capabilities of the central detectors. The study of such processes helps in understanding the dynamics of Pomeron exchanges and its connection to soft QCD. Since Pomeron exchanges are gluon-rich processes the enhanced glueball production is expected: resonance spectrum study is to be performed in order to search for possible glueball candidates. ALICE results from Run 1 & 2 and the perspectives for LHC Run 3 & 4 on diffractive measurements are discussed in the talk.

Photon-induced reactions are studied in ultra-peripheral p-Pb and Pb-Pb collisions because of the high photon flux from lead ions, which is proportional to the square of the ion charge. Measurements of vector meson photoproduction in ultra-peripheral collisions are of particular interest, allowing one to probe the gluon PDFs and study poorly known nuclear gluon shadowing effects in a wide range of Bjorken-x. The ALICE results on vector meson photoproduction are presented and perspectives for future measurements are outlined.

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## Challenges in searches for dark matter at the LHC in forward proton mode

**Author:** Valery Khoze<sup>1</sup>

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We discuss the prospects of searches for pair production at the LHC with forward proton detectors of new BSM states with subsequent decays into cosmologically stable dark matter.

As a topical example we consider production of slepton and chargino pairs in the MSSM with compressed mass spectra, where the natural candidate for cold dark matter is the lightest neutralino.

Special attention is paid to various challenges which such searches face in the case of high pile-up environment.

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## Challenges in searches for dark matter at the LHC in forward proton mode.

**Author:** Valery Khoze<sup>1</sup>

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We discuss the prospects of searches for pair production at the LHC with forward proton detectors of new BSM states with subsequent decays into cosmologically stable dark matter.

As a topical example we consider production of slepton and chargino pairs in the MSSM with compressed mass spectra, where the natural candidate for cold dark matter is the lightest neutralino.

Special attention is paid to various challenges which such searches face in the case of high pile-up environment.

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## PROSA PDFs and astrophysical applications

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The PROSA parton distribution function fit was the first one appeared in the literature incorporating data on open charm and open bottom hadroproduction at LHCb, in order to reduce the uncertainties on gluons and sea quarks at low  $x$ 's ( $x < 10^{-4}$ ).

We will present recent developments of the PROSA PDFs, of particular relevance for their usage in the field of Neutrino Astronomy, and their

application in the computation of key quantities for the analyses of high-energy data at Very Large Volume Neutrino Telescopes.

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## Diffractive PDFs measurements at the LHeC

**Author:** Krzysztof Golec-Biernat<sup>1</sup>

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Possible diffractive PDFs measurements at the LHeC will be presented.

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## Recent Results of the RHIC Spin Physics Program

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The Relativistic Heavy Ion Collider (RHIC) is a unique facility as it is the world's only polarized-proton + proton collider capable of delivering highly polarized protons at  $\sqrt{s} = 200/500$  GeV. Using longitudinally polarized protons, RHIC is able to probe the longitudinal spin structure of the proton through  $W$ ,  $A$  and  $W$ , jet, hadron, and di-jet ALL measurements, providing constraints on the sea quark and gluon polarization distributions. Furthermore, using transversely polarized protons RHIC can probe the transverse spin structure of the proton such as transversity, the Collins fragmentation function, and the Sivers function, through  $W$ , jet, di-hadron, and  $W$  and  $A$  T measurements. Presented here is a brief summary of the recent results of the STAR and PHENIX proton + proton data at RHIC, which are playing a key role in our understanding of the proton spin structure.

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## Recent COMPASS results on the measurement of spin-dependent azimuthal asymmetries in SIDIS and Drell-Yan}

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COMPASS is a high energy physics experiment at CERN (SPS, M2 beamline). One of the main objectives of the experiment is the study of the transverse spin structure of the nucleon through measurement of target spin (in)dependent azimuthal asymmetries in semi-Inclusive Deep Inelastic Scattering and Drell-Yan processes with transversely polarized targets. Within the QCD improved parton model approach, these physics observables are interpreted in terms of convolutions of quark Transverse Momentum Dependent (TMD) Parton Distribution Functions (PDFs) of the nucleon and TMD Fragmentation Functions (in SIDIS), or of the beam hadron TMD PDFs (in Drell-Yan). In general the nucleon TMD PDFs are supposed to be process-independent, with the exception of time-reversal odd Sivers and Boer-Mulders TMD PDFs which are expected to have opposite sign when measured in SIDIS and in Drell-Yan. The latter conjecture is based on gauge invariance of QCD and is considered to be a fundamental test of TMD factorization framework.

Between 2002 and 2010 COMPASS performed a series of SIDIS measurements, using a longitudinally polarized muon beam scattering off transversely polarized  ${}^6\text{LiD}$  or  $\text{NH}_3$  targets. In 2015 the experiment collected first ever single-polarized DY data, using a  $190 \text{ GeV}/c \pi^-$  beam impinging on a transversely polarized  $\text{NH}_3$  target. Thus, COMPASS became the only facility exploring the transverse spin structure of the nucleon via two alternative mechanisms. The measurements were done at a similar kinematic range using mostly the same experimental setup and polarized target configurations. This opens the unique opportunity to study the universality of the TMD PDFs and to test the predicted sign-change of Sivers and Boer-Mulders TMD PDFs.

In this talk, recent Drell-Yan and relevant SIDIS results obtained by COMPASS experiment will be presented. The role and importance of the results for the general understanding of the transverse-spin structure of the nucleon will be underlined.

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## Parton Distributions and small-x physics with the LHeC and the FCC-eh

**Author:** Claire Gwenlan<sup>1</sup>

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Energy-frontier DIS can be realised at CERN through an energy recovery linac that would produce 60 GeV electrons to collide with the HL-LHC or later HE-LHC (LHeC) or eventually the FCC hadron beams (FCC-eh). It would deliver electron-proton collisions with centre-of-mass energies in the range 0.3-3.5 TeV, and luminosities exceeding  $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ . In this talk we will present new studies on the prospects for the precise and complete determination of parton distributions in the proton in inclusive deep inelastic scattering. We will then discuss possible ways for establishing the existence of new QCD physics at small x, of BFKL type, through the discovery of a new regime beyond the dilute one described by fixed-order perturbation theory.

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## Welcome

**Corresponding Authors:** papa@cs.infn.it, christophe.royon@cern.ch

**Diffraction and photon physics in pp and heavy ions session / 99**

## Recent Elastic and Total Cross-Section Measurements by TOTEM

**Corresponding Author:** valentina.avati@cern.ch

**Diffraction and photon physics in pp and heavy ions session / 100**

## Measurements of elastic pp interactions and exclusive production with the ATLAS detector

**Corresponding Author:** alessia.bruni@bo.infn.it

Diffraction and photon physics in pp and heavy ions session / 101

### **Measurement of Total and Elastic Cross Sections at $\sqrt{s}=200\sim\text{GeV}$ with the STAR Detector at RHIC**

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Diffraction and photon physics in pp and heavy ions session / 102

### **New physics from TOTEM's recent measurements of elastic and total cross sections**

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Diffraction and photon physics in pp and heavy ions session / 103

### **The odderon: myths and reality**

**Corresponding Author:** jenk@bitp.kiev.ua

Diffraction and photon physics in pp and heavy ions session / 104

### **The Odderon and the LHC data**

**Corresponding Author:** selugin@theor.jinr.ru

Diffraction and photon physics in pp and heavy ions session / 105

### **Effects of absorption in single-spin asymmetry of small-angle elastic scattering**

**Corresponding Author:** michal.krelina@cern.ch

Diffraction and photon physics in pp and heavy ions session / 106

### **Recent CMS results on inelastic cross section measurements**

**Corresponding Author:** sercan.sen@cern.ch

**Diffraction and photon physics in pp and heavy ions session / 107**

## **Discussion session: elastic, total cross section, odderon, soft diffraction**

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**Low x, PDFs and hadronic final state session / 108**

## **Combination and QCD analysis of beauty and charm production cross section measurements in deep inelastic ep scattering at HERA**

**Corresponding Author:** uri.karshon@weizmann.ac.il

**Low x, PDFs and hadronic final state session / 109**

## **Latest Results on MMHT PDF Fits**

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**Low x, PDFs and hadronic final state session / 110**

## **Constraints on the Parton Density Functions of the Proton by Measurements with the ATLAS Detector**

**Corresponding Author:** c.gwenlan1@physics.ox.ac.uk

**Low x, PDFs and hadronic final state session / 111**

## **QCD analysis of the ATLAS and CMS W and Z cross-section measurements and implications for the strange sea density**

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**Low x, PDFs and hadronic final state session / 112**

## **Recent developments in Small-x Resummation**

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**Low x, PDFs and hadronic final state session / 113**

### **Discussion session: QCD fits, PDFs**

**Corresponding Authors:** lech.szymanowski@fuw.edu.pl, paolo.gunnellini@cern.ch, amanda.cooper-sarkar@physics.ox.ac.uk

**Low x, PDFs and hadronic final state session / 114**

### **Parton Distributions and small-x physics with the LHeC and the FCC-eh**

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**Low x, PDFs and hadronic final state session / 115**

### **Impact of low-x resummation on QCD analysis of HERA data**

**Corresponding Author:** amanda.cooper-sarkar@physics.ox.ac.uk

**Low x, PDFs and hadronic final state session / 116**

### **Recent CMS results on soft and small-x QCD physics**

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### **Symposium in honor of Lev Lipatov**

**Diffraction and photon physics in pp and heavy ions session / 118**

### **Recent results from PPS and prospects**

**Corresponding Author:** k.shchelina@cern.ch

**Diffraction and photon physics in pp and heavy ions session / 119**

### **The PPS detector: status and performance**

**Corresponding Author:** ada.solano@cern.ch

Diffraction and photon physics in pp and heavy ions session / 120

## **Photon-Photon scattering in the resonance region at midrapidity at the LHC**

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Diffraction and photon physics in pp and heavy ions session / 121

## **Searching for axion-like particles with proton tagging**

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Diffraction and photon physics in pp and heavy ions session / 122

## **Anomalous coupling studies at the LHC with intact protons**

Corresponding Author: [christophe.royon@cern.ch](mailto:christophe.royon@cern.ch)

Diffraction and photon physics in pp and heavy ions session / 123

## **Rapidity gap survival factors caused by remnant fragmentation for central electromagnetic production of $W+W^-$**

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Diffraction and photon physics in pp and heavy ions session / 124

## **Challenges in searches for dark matter at the LHC in forward proton mode**

Corresponding Author: [v.a.khoze@durham.ac.uk](mailto:v.a.khoze@durham.ac.uk)

Diffraction and photon physics in pp and heavy ions session / 125

## **Measurement of the exclusive $\gamma\text{-}\gamma\text{-}\rightarrow\mu^+\mu^-$ process in proton-proton collisions at $\sqrt{s}=13$ TeV with the ATLAS detector (tbc)**

Diffraction and photon physics in pp and heavy ions session / 126



## **Discussion session: gamma gamma physics and BSM**

**Corresponding Authors:** christina.mesropian@cern.ch, valentina.avati@cern.ch, boris.kopeliovich@usm.cl, a.d.martin@durham.ac.uk

Low x, PDFs and hadronic final state session / 127

## **Two particle correlations at LHCb**

**Corresponding Author:** marcin.kucharczyk@cern.ch

Low x, PDFs and hadronic final state session / 128

## **PROSA PDFs and astrophysical applications**

**Corresponding Author:** maria.garzelli@mi.infn.it

Low x, PDFs and hadronic final state session / 129

## **Leptoproduction of rho-mesons as discriminator for the unintegrated gluon distribution in the proton**

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Low x, PDFs and hadronic final state session / 130

## **Forward Drell-Yan plus jet production as a probe of the BFKL dynamics**

**Corresponding Author:** krzysztof.golec-biernat@ifj.edu.pl

Low x, PDFs and hadronic final state session / 131

## **Toward Mueller-Tang Jets at Next-to-Leading Order**

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Low x, PDFs and hadronic final state session / 132

## **Discussion session: Low x, BFKL, PDFs**

Low x, PDFs and hadronic final state session / 133

## **On double pomeron exchange in J/psi hadroproduction**

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Low x, PDFs and hadronic final state session / 134

## **Scaling function for the production of vector mesons and DVCS in the saturation scheme**

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Low x, PDFs and hadronic final state session / 135

## **Vector meson photoproduction: Recent results**

Corresponding Authors: barros@ufpel.edu.br, victorpbg@gmail.com

Low x, PDFs and hadronic final state session / 136

## **Towards a Neural Network determination of nuclear parton distribution functions**

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Spin physics session / 137

## **Recent Results of the RHIC Spin Physics Program**

Corresponding Authors: mposik1983@gmail.com, posik@temple.edu

Spin physics session / 138

## **Single-Spin Asymmetry Measurement of Very Forward Neutral Particle Production in the RHICf experiment**

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Spin physics session / 139

## **Recent COMPASS results on the measurement of spin-dependent azimuthal asymmetries in SIDIS and Drell-Yan**

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Spin physics session / 140

## **Polarization observables in $\chi_c$ to $J/\psi + \mu + \mu$ Dalitz decays at the LHC**

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Spin physics session / 141

## **Probing gluon TMDs in $J/\psi$ and Upsilon production at an EIC**

**Corresponding Author:** pieter.taels@pv.infn.it

Spin physics session / 142

## **Twist-2 transverse momentum distributions at NNLO in QCD**

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Spin physics session / 143

## **Probing Generalized Parton Distributions through the photoproduction of a photon-meson pair**

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Spin physics session / 144

## **Nucleon spin structure from lattice QCD**

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Spin physics session / 145

## **Spin Physics Opportunities at an EIC**

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**Spin physics session / 146**

### **Discussion session: spin physics**

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**QCD and parton saturation physics session / 147**

### **Probing perturbative QCD at the ATLAS Experiment**

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**QCD and parton saturation physics session / 148**

### **Measuring jet substructure observables at the ATLAS Experiment**

**Corresponding Author:** andrei.minaenko@cern.ch

**QCD and parton saturation physics session / 149**

### **NNLLA BFKL and Regge cuts**

**Corresponding Author:** vsfadin@yandex.ru

**QCD and parton saturation physics session / 150**

### **From BFKL to the soft Pomeron - an attempt to find an interpolation**

**QCD and parton saturation physics session / 151**

### **Amplitudes in the Multi-Regge Limit of N=4 SYM**

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**QCD and parton saturation physics session / 152**

## **Inclusive hadron-jet production at the LHC**

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QCD and parton saturation physics session / 153

## **Crossing the bridge from BFKL to saturation**

**Corresponding Author:** traben13@gmail.com

QCD and parton saturation physics session / 154

## **Particle multiplicities in the central region of high-energy collisions from $k_T$ -factorization with running coupling corrections**

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QCD and parton saturation physics session / 155

## **Discussion session: BFKL, saturation**

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Diffraction in ep and eA / 156

## **Fits to high-x data and measurement of charm production in charged current**

**Corresponding Author:** ada.solano@cern.ch

Diffraction in ep and eA / 157

## **b production via a double muon tag**

**Corresponding Author:** alessia.bruni@bo.infn.it

Diffraction in ep and eA / 158

## **Collective effects in DIS at HERA**

**Corresponding Author:** ruspa@to.infn.it

Diffraction in ep and eA / 159

## **Exclusive rho and rho' photoproduction at HERA**

**Corresponding Author:** levonian@mail.desy.de

Diffraction in ep and eA / 160

## **Diffractive PDFs measurements at the LHeC**

**Corresponding Author:** krzysztof.golec-biernat@ifj.edu.pl

Diffraction in ep and eA / 161

## **Diffractive electron-nucleus scattering and ancestry in branching random walks**

**Corresponding Author:** stephane.munier@cpht.polytechnique.fr

Diffraction in ep and eA / 162

## **KG18 diffractive parton distribution functions and their uncertainties in the xFitter framework**

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Diffraction in ep and eA / 163

## **Proton Spin in Deep Inelastic Scattering**

**Corresponding Author:** b.povh@mpi-hd.mpg.de

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## **The EIC project: physics and status**

Diffraction in ep and eA / 165

## **Discussion session: ep and eA physics**

**Corresponding Authors:** ruspa@to.infn.it, abhay.deshpande@stonybrook.edu

**Low x, PDFs and hadronic final state session / 166**

## **Multi particle production in proton-nucleus collisions**

**Corresponding Author:** yair25m@gmail.com

**Low x, PDFs and hadronic final state session / 167**

## **New Results on Multi-Boson Production with the ATLAS Detector**

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**Diffraction and photon physics in pp and heavy ions session / 168**

## **Recent results on Central Exclusive Production with the STAR detector at RHIC**

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**Diffraction and photon physics in pp and heavy ions session / 169**

## **Central exclusive production at LHCb**

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**Diffraction and photon physics in pp and heavy ions session / 170**

## **Measurements of particle spectra in diffractive p+p collisions with the STAR detector at RHIC**

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**Diffraction and photon physics in pp and heavy ions session / 171**

## **Exclusive central production of the Pomeron tensor state in high-energy collisions of protons**

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Diffraction and photon physics in pp and heavy ions session / 172

## **Superchic supercharged: an updated generator for exclusive production**

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Diffraction and photon physics in pp and heavy ions session / 173

## **Algorithmics of Diffraction**

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Diffraction and photon physics in pp and heavy ions session / 174

## **Discussion session: exclusive diffraction**

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QCD and parton saturation physics session / 175

## **Diffraction dijets: breakdown of factorization**

**Corresponding Author:** boris.kopeliovich@usm.cl

QCD and parton saturation physics session / 176

## **A model-independent method to extract $B(t)$ , $\rho(t)$ and the anomalous dimension of QCD from elastic pp scattering**

**Corresponding Author:** tamas.ferenc.csorgo@cern.ch

QCD and parton saturation physics session / 177

## **A Model for Soft and Hard Interactions based on the CGC/Saturation Approach**

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## **Exclusive vector meson production in the QCD shockwave approach**

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QCD and parton saturation physics session / 179

## **Possible solution of J/psi polarization puzzle in the CGC+NRQCD approach**

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QCD and parton saturation physics session / 180

## **Fluctuations in dilute systems**

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QCD and parton saturation physics session / 181

## **Entropy production and its time evolution in High energy energy QCD**

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QCD and parton saturation physics session / 182

## **Effects of saturation in high-multiplicity pp collisions**

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QCD and parton saturation physics session / 183

## **Vector meson electro-production within the energy-dependent hot-spot model**

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QCD and parton saturation physics session / 184

### **Discussion session: soft/hard diffraction, vector mesons, factorization breaking**

Diffraction and photon physics in pp and heavy ions session / 185

### **Exclusive J/psi production in PbPb collisions at LHCb**

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Diffraction and photon physics in pp and heavy ions session / 186

### **Heavy Meson Coherent Photoproduction in (Ultra)-Peripheral AA Collisions**

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Diffraction and photon physics in pp and heavy ions session / 187

### **Jet, Vector meson and photon production and photon production in pA and AA collisions in CMS**

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Diffraction and photon physics in pp and heavy ions session / 188

### **Latest results of diffractive and exclusive measurements with CMS**

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Diffraction and photon physics in pp and heavy ions session / 189

### **Forward physics results and perspectives with ALICE at the LHC**

Corresponding Author: sergey.evdokimov@cern.ch

Diffraction and photon physics in pp and heavy ions session / 190

## Universal suppression in production of different high-pT hadrons in heavy ion collisions

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Diffraction and photon physics in pp and heavy ions session / 191

## Heavy quarkonium and dynamical gluon mass at non-zero temperature in instanton vacuum model

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## Discussion session: heavy ions

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## Workshop conclusion

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## Spin Physics Opportunities at an EIC

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A high luminosity polarized Electron-Ion Collider (EIC) with high and variable energy will offer unique opportunities to study the spin of the nucleon, its internal dynamics, and low-x phenomena. The nuclear science community aims to realize such a collider in the United States as an upgrade to either the existing Relativistic Heavy Ion Collider or the Thomas Jefferson National Accelerator Facility. This talk will discuss the status and scientific prospects for low-x and spin physics at such an EIC.

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## Double-Logarithmic contribution to Pomeron

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