

# **Diffraction 2010**

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## **Book of Abstracts**



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## Deconfinement: role of coherent rotation effects and reflective scattering in hadron and nucleus collisions

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

<sup>1</sup> IHEP, Protvino, Russia

**Corresponding Author:** sergey.troshin@ihep.ru

The role of reflective scattering in formation of the deconfined state will be discussed along with the role of rotating matter coherent effects. These effects lead to the new interesting conclusions on the phase structure of strongly interacting matter and quark-gluon plasma formation.

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## $\pi$ -p and $\pi$ - $\pi$ scattering: towards the first LHC results

**Author:** Roman Ryutin<sup>1</sup>

**Co-authors:** Andrei Sobol <sup>1</sup>; Vladimir Petrov <sup>2</sup>

<sup>1</sup> IHEP, Protvino

<sup>2</sup> IHEP, Protvino

**Corresponding Author:** roman.rioutine@cern.ch

We discuss a possibility of an experiment at the LHC with leading neutrons production (charge exchange and double charge exchange processes). The latter could be used to extract from it  $\pi^+p$  and  $\pi^+\pi^+$  cross-sections. In this work we give some estimates for the cases of total, elastic and inclusive di-jet cross-sections and discuss related problems and prospects. All the steps from the theory to the experimental simulation of the signal and possible backgrounds are presented. These measurements could provide us with the first fundamental results from LHC.

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## First Data from the TOTEM experiment at LHC

**Author:** Fabrizio Ferro<sup>1</sup>

<sup>1</sup> GE

Totem is the only LHC experiment that will explore the forward region at pseudorapidity larger than 3.1

The main goal is the measurement of the total and elastic cross-section at 14 TeV and the study of diffractive physics in the forward region. The experiment approved and funded in the 2006, was build, largely commissioned and started his data taking in December 2009.

The total cross section beyond 1 TeV/c will be measured with the unprecedented precision of 1 % using the luminosity independent method based on the simultaneous detection of elastic scattering at low momentum transfer and of the inelastic interactions.

Protons scattered at very small angles in elastic or quasi-elastic reactions will be measured in telescopes of silicon detectors enclosed in Roman Pots, placed on both sides of the intersection regions. Inelastically produced secondaries will be measured by a forward inelastic detector covering the region  $3 < \eta < 7$  with full azimuthal acceptance. This last detector will measure the overall rate of inelastic reactions.

The TOTEM physics program also include for the first time the measurement of the charged multiplicity at the TEV scale important for the understanding of the cosmic ray events. TOTEM will take data under all LHC beam conditions including standard high luminosity runs to maximize its physics goals. We will describe the status of the TOTEM experiment. A first set of data at 0.9 and 2.36 TeV was collected in December 2009 and we taking data at 3.5 TeV. This contribution will also include some preliminary results obtained from data. In addition we will discuss the measurements to be made in the 2010 LHC runs.

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## Gluon saturation and particle production at LHC

**Author:** Amir Rezaeian<sup>1</sup>

**Co-author:** Genya Levin<sup>2</sup>

<sup>1</sup> *Santa Maria Universidad*

<sup>2</sup> *Tel Aviv University*

**Corresponding Author:** amir.rezaeian@usm.cl

In high density QCD the hadron production stems from decay of mini-jets that have the transverse momenta of the order of the saturation scale. I will show that this idea is able to describe in a unique fashion the first data from the LHC for the inclusive charged-hadron production in pp collisions, the deep inelastic scattering at HERA at small Bjorken- $x$ , and the hadron multiplicities in AA collisions at RHIC. Recently reported data from ALICE, CMS and ATLAS including inclusive charged-hadron transverse-momentum and multiplicity distribution in pp collisions are well described in our approach. We provide quantitative predictions for the rapidity, centrality and energy dependencies of inclusive charged-hadron productions for the LHC in AA collisions based on the idea of gluon saturation in the color-glass condensate framework. I will also discuss the importance of saturation/shadowing effects in pA collisions at LHC.

My talk is partly based on the following papers:

E. Levin and A. H. Rezaeian, arXiv:1007.2430(submitted to PRD);

E. Levin and A. H. Rezaeian, arXiv:1005.0631 (PRD 82, 014022,2010);

A. H. Rezaeian and A. Schaefer, arXiv:0908.3695 (PRD 81,114032,2010).

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## W Boson Production in Polarized p+p Collisions at RHIC

**Author:** George Igo<sup>1</sup>

<sup>1</sup> *University of California Los Angeles*

The production of W bosons in longitudinally polarized p+p collisions at RHIC provides a new means of studying the spin-flavor asymmetries of the proton sea quark distributions. W bosons are produced in  $\bar{u}+d(\bar{d}+u)$  collisions and can be detected through their leptonic decays where only the charged lepton is detected. Precise tracking information, provided by the STAR Time Projection Chamber (TPC) at mid-rapidity, allows for a determination of the charge sign of the high  $p_T$   $e^-$ (+). The large acceptance of the TPC and Electromagnetic Calorimeters is well suited to place isolation requirements on the  $e^-$ (+) and to veto on the away side energy, which reduces the large QCD background by several orders of magnitude, yielding a clean W signal. Preliminary results for the W production cross section and parity-violating single-spin asymmetry  $A_L$  from the STAR Collaborations 2009 data at  $\sqrt{s} = 500$  GeV, as well as future



projections of the STAR W spin program at mid-rapidity and forward rapidity, will be presented.

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## The photon impact factor for DIS at NLO: analytic result

**Author:** Giovanni Antonio Chirilli<sup>1</sup>

<sup>1</sup> *Cpht-Polytechnique & LPT d'Orsay*

To study the scattering amplitudes at the high-energy, the T-product of two currents can be expanded in terms of coefficient functions (impact factors) and matrix elements of composite color dipoles made of Wilson line with rapidity cutoff preserving conformal invariance.

In the leading order, the high-energy evolution of color dipoles is governed by the non-linear Balitsky-Kovchegov (BK) equation. To describe the high-energy amplitudes in the next-to-leading order (NLO) one needs to know the coefficient function (impact factor) and the evolution of corresponding Wilson-line operators at NLO. Using the high-energy OPE, we find the next-to-leading order (NLO) correction to the BK equation and calculate the impact factor for virtual photons in deep inelastic scattering.

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## Anomalous WW gamma quartic and trilinear coupling in photon-induced processes

**Author:** Christophe Royon Royon<sup>1</sup>

<sup>1</sup> *IRFU-SPP, CEA Saclay*

**Corresponding Author:** christophe.royon@cea.fr

We present a new method to test the Standard Model expectations at the LHC using photon-induced WW production. Both W decay in the main ATLAS or CMS detectors while scattered protons are measured in forward detectors.

The sensitivity to anomalous WW gamma quartic and triple gauge coupling can be improved respectively by more than three orders of magnitude or a factor 30 compared to the present LEP limits.

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## A spectral representation for the baryon to meson and baryon to photon TDAs

**Author:** Kirill Semenov-Tian-Shansky<sup>1</sup>

**Co-authors:** Bernard Pire<sup>2</sup>; Lech Szymanowski<sup>3</sup>

<sup>1</sup> *CPHT Ecole Polytechnique, LPT Orsay*

<sup>2</sup> CPHT Ecole Polytechnique

<sup>3</sup> Institute for Nuclear Studies, Warsaw, Poland

**Corresponding Author:** kirill.semenov@cpht.polytechnique.fr

The concept of generalized parton distributions (GPDs), non-diagonal matrix elements of quark-antiquark or gluon-gluon non local operators on the light cone, has recently been extended to baryon to meson and (and baryon to baryon) transition distribution amplitudes (TDAs), non diagonal matrix elements of three quark operators between two hadronic states of different baryon number (or between a baryon state and a photon).

These objects are useful for the description of exclusive processes characterized by a baryonic exchange such as backward deeply virtual Compton scattering backward electroproduction of mesons or proton-antiproton annihilation. Nucleon to meson TDAs are also considered to be a useful tool to quantify the pion cloud in the baryons.

In this talk we address the problem of construction of a spectral representation of baryon to meson (and baryon to photon) transition distribution amplitudes.

We introduce the notion of quadruple distributions and generalize A. Radyushkin's factorized Ansatz for this issue.

This allows the modeling of baryon to meson and baryon to photon TDAs in the complete domain of their definition and quantitative rate estimates in various hard exclusive reactions.

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## Hadron inclusive production at the LHC.

**Author:** Eugene Levin<sup>1</sup>

<sup>1</sup> UTFSM and Tel Aviv University

**Corresponding Author:** leving@post.tau.ac.il

Two main approaches will be discussed. The first one is the high energy phenomenology based on Pomeron interactions. The main questions that I would like to answer, is what kind of soft model can we trust theoretically and what we can predict for the inclusive production at LHC.

The second approach is the gluon saturation (Color Glass Condensate) in which the hadron production stems from the decay of gluon mini-jet with transverse momenta of the order of the saturation scale into hadrons. I will show that this approach reproduces the main features of the LHC data.

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## Fitting HERA data at low-x Using a Modified BFKL Kernel

**Author:** Douglas Ross<sup>1</sup>

<sup>1</sup> Southampton University

**Corresponding Author:** doug@soton.ac.uk

Using a modification of the BFKL equation which admits discrete pomeron pole solutions, we obtain a good fit to HERA data on structure functions at low-x, including the  $Q^2$  dependence of the  $1/x$

slope. The fit is very sensitive to the running of the QCD coupling, up to high energies and therefore sensitive to any new physics which may be encountered. It is suggested that the quality of such fits could provide “fossil evidence” for Physics Beyond the Standard Model even though the data analyzed are at energies far below the threshold for any such new Physics.

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## Prospects for DVCS Measurements using COMPASS spectrometer at CERN

**Author:** Oleg Kouznetsov<sup>1</sup>

<sup>1</sup> CEA Saclay

**Corresponding Author:** oleg.kouznetsov@cea.fr

The high energies polarized muon beams available at CERN, and the option of using either positive or negative ones, give to the COMPASS experiment an excellent opportunity for studying Generalized Parton Distributions (GPD), through Deeply Virtual Compton Scattering (DVCS). The GPD formalism provides a link between the transverse position and the momentum distributions of partons inside the nucleon. Moreover, the second moment of

GPDs gives access to the total angular momentum carried by partons. That brings a new insight on the more than 20 years old nucleon spin puzzle.

In the full-scale programme, two running periods are considered, with the first one using an unpolarized proton target. We propose to measure the slope of the momentum transfer distribution which is known to reflect the size of the partonic object on which the DVCS process took place. The dependence of the slope can be measured as a function of  $x_{Bj}$  to observe possible shrinkage of the nucleon size for increase values of  $x_{Bj}$ . Furthermore, the beam charge and spin difference will be measured and the Compton Form Factor involving the GPD  $H$  will be determined over a wide kinematical range.

At a second stage we consider to use a transversely polarized proton target, in order to collect data that constrain the GPD  $E$ .

In the view of future GPD measurements two DVCS test runs were performed in 2008 and 2009 years.

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## Diffraction open charm production at HERA: experiment versus two-gluon exchange model

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

<sup>1</sup> P.N.Lebedev Institute of Physics

**Corresponding Author:** baranov@sci.lebedev.ru

Diffraction production of  $D^*$  mesons at HERA is considered in the framework of collinear two-gluon exchange model. Theoretical results are compared with recent experimental data collected by the H1 and ZEUS collaborations both in the real photoproduction and the deep inelastic regimes, and a reasonably good agreement is found in all cases.

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## DVCS @ HERMES: An Overview

**Author:** Morgan Murray<sup>1</sup>

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

**Corresponding Author:** morgan@physics.gla.ac.uk

The study of Generalised Parton Distributions (GPDs) promises to provide new knowledge of the structure of the nucleon, including, most notably, access to the total angular momentum of quarks within the nucleon. It can be difficult to ascertain new information on the distributions, but amongst all the exclusive processes that can provide access, Deeply Virtual Compton Scattering (DVCS) is relatively simple and experimentally accessible. The HERMES collaboration has the most diverse results pertaining to DVCS of any experiment, extracting asymmetries in the azimuthal distribution of produced photons according to both beam helicity and charge and target spin state. In this talk, we provide an overview of the HERMES DVCS result catalogue and explain how the results are used to improve constraints on the underlying GPDs. An indication of the progress in extracting DVCS results using truly exclusive measurements at HERMES using the Recoil Detector will also be provided.

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## Estimation of single and double diffractive heavy quarks production at the LHC

**Author:** Mairon Machado<sup>1</sup>

**Co-authors:** Magno Valério Machado<sup>1</sup>; Maria Beatriz Gay Ducati<sup>1</sup>

<sup>1</sup> *GFPAE - IF - UFRGS*

**Corresponding Author:** melo.machado@ufrgs.br

The single and double diffractive cross sections for heavy quarks production are evaluated at NLO accuracy for hadronic and heavy ion collision at the LHC. Diffractive production of charm, and bottom, is the main subject of this work and predictions for Ca-Ca, Pb-Pb and p-Pb collision are provided. The hard diffraction formalism is considered using Regge factorization, where the Pomeron is constituted by parton. At high energies, these partons are predominantly gluons. A recent parametrization to the Pomeron structure function (DPDF) is applied and absorptive corrections are taken into account as well. The diffractive ratios are estimated and theoretical uncertainties are presented.

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## Diffractive Higgs boson photoproduction in Ultraperipheral Collisions at LHC

**Author:** Gustavo Gil da Silveira<sup>1</sup>

**Co-author:** Maria Beatriz Gay Ducati<sup>1</sup>

<sup>1</sup> *Universidade Federal do Rio Grande do Sul*

**Corresponding Author:** gustavo.silveira@ufrgs.br

A new mechanism is presented for the Central Exclusive Diffractive production of the Standard Model Higgs boson in Ultraperipheral Collisions at LHC. The Higgs boson is centrally produced by Double Pomeron Exchange with two Large Rapidity Gaps emerging in the final state, being the main experimental signature for this process. The Higgs boson photoproduction is studied within this new mechanism in proton-proton and proton-nucleus collisions, where the photon flux has to be introduced in a particular way for each source object. As a result, this mechanism predicts a production cross section in proton-proton collisions of about 2 fb, which is similar to that obtained in Pomeron-Pomeron processes. Besides, the cross section in proton-lead collisions rises to about 0.6 pb, being comparable with the results of two-photon processes in proton-gold collisions. Therefore, as the Rapidity Gap Survival Probability is an open question in high-energy Physics, an analysis of different probabilities shows how competitive are these approaches for the Higgs boson production in the LHC kinematical regime.

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## Single Diffractive Higgs Production at the LHC

**Author:** M.Beatriz Gay Ducati<sup>1</sup>

<sup>1</sup> *Universidade Federal do Rio Grande do Sul- UFRGS*

**Corresponding Author:** beatriz.gay@ufrgs.br

The single diffractive production of the Standard Model Higgs boson is computed using the diffractive factorization formalism, taking into account a parametrization for the Pomeron structure function provided by the H1 Collaboration. We compute the cross sections at NLO accuracy for the gluon fusion process, since it is the leading mechanism to the Higgs boson production. The gap survival probability is also introduced to account for the rescattering corrections due to spectator particles present in the interaction. The single diffractive ratio is predicted to proton-proton collisions at the LHC, once the beam luminosity is favorable to the diffractive events in the LHC kinematical regime, with the inclusive and diffractive cross sections computed considering NLO corrections.

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## Long range hadron potential and the fine structure of the diffraction peak

**Author:** Oleg Selyugin<sup>1</sup>

**Co-author:** Jean-Rene Cudell<sup>2</sup>

<sup>1</sup> *JINR*

<sup>2</sup> *University of Liege*

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

A new analysis of the differential cross sections of the elastic proton-proton and proton-antiproton scattering in a wide energy region from  $\sqrt{s} > 3$  GeV up to  $\sqrt{s} = 1800$  GeV in the Coulomb-hadron interference region was carried out to search for the existence of special structures over the background exponential behavior of the diffraction peak.

On the basis of many statistical data one finds a new phenomenon - a new periodic structure in the differential cross sections at small momentum transfer. We analyzed this phenomena through two independent methods. One is the standard fitting method using the  $\chi^2$  minimization and adding a small additional periodic function (Sin, Cos, Bessel function ...). The second method is based on the choice of two independent statistical samples. This method does not depend on the form of the

periodic structure and gives the true probability for the presence a new effect. The basic characteristic of the periodic structure (period, amplitude and starting phase) were determined from the coincidence of the results of both methods. It was shown that the size of the new effect is determined by the size of the small additional periodic part of the hadron elastic scattering amplitude and its interference with the Coulomb amplitude in the small momentum transfer region. The properties of the corresponding additional part of the hadron interaction potential are discussed.

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## Low-mass diffraction dissociation at the LHC

**Author:** Laszlo Jenkovszky<sup>1</sup>

<sup>1</sup> *Bogolyubov Institute for Theoretical Physics, National Academy of Sciences of Ukraine*

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

A models for low missing mass  $M_X$  diffraction dissociation (DD), based on the factorization properties of the high-energy, Pomeron-exchange scattering amplitude, is constructed. The properties of the inelastic  $Pp \rightarrow M_X$  transition form factors (inelastic vertices) are those known from  $\gamma$ -p scattering at JLab, with the photon-Pomeron similarity assumed. The direct-channel, low-energy (=missing mass) baryon (protonic) trajectory is a non-linear, complex function providing for finite widths of baryon resonance lying on the protonic trajectory. The validity of finite-mass sum rules is tested, and predictions for low-mass DD cross sections at the LHC are given.

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## Critical Phenomena in DIS

**Author:** Laszlo Jenkovszky<sup>1</sup>

<sup>1</sup> *Bogolyubov Institute for Theoretical Physics, National Academy of Sciences of Ukraine*

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

Saturation in deep inelastic scattering (DIS) and deeply virtual Compton scattering (DVCS) is associated with a phase transition between the partonic gas, typical of moderate  $x$  and  $Q^2$ , and, a partonic fluid, created at increasing  $Q^2$  and decreasing Bjorken  $x$ . In the statistical interpretation of DIS, the large- $x$ ,  $(1-x)^n$  factor in the structure function (SF) is associated with a perfect gas, while the low-, Regge-behaved factor  $x^{b(Q^2)}$  is responsible for the deviation from the perfect gas and ultimately leads to a gas-liquid phase transition.

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## Exclusive production of vector mesons in $pp$ and $p\bar{p}$ collisions.

**Author:** Anna Cisek<sup>1</sup>

**Co-authors:** Antoni Szczurek<sup>1</sup>; Wolfgang Schafer<sup>1</sup>

<sup>1</sup> *Institute of Nuclear Physics PAN, Krakow*

**Corresponding Author:** anna.cisek@ifj.edu.pl

Protons and antiprotons at collider energies are a source of high energy Weizsäcker–Williams photons. This opens up a possibility to study at the LHC exclusive photoproduction of heavy vector mesons at energies much larger than possible at the HERA accelerator.

We present selected results on the production of vector mesons  $\rho$ ,  $\omega$ ,  $\phi$ ,  $J/\Psi$  and  $\Upsilon$ . I will show distributions in rapidity, transverse momentum of mesons and azimuthal angle between outgoing protons for RHIC, Tevatron and LHC energies. The absorption effects are discussed.

The amplitude for  $\gamma p \rightarrow \phi p$  is calculated in a pQCD  $k_T$ -factorization approach with an unintegrated gluon distribution constrained by inclusive deep-inelastic structure function. The total cross section for diffractive meson (virtual) photo-production as a function of energy and photon virtuality is calculated and compared to HERA data. We also discuss the ratio of the first radial excitation state (2S) to the ground state (1S) in diffractive  $J/\Psi$  and  $\Upsilon$  production.

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## Recent progress in the statistical approach of the parton distributions

**Author:** Jacques Soffer<sup>1</sup>

<sup>1</sup> Temple University, Philadelphia, PA, USA

**Corresponding Author:** jacques.soffer@gmail.com

We first recall some recent successful predictions obtained from the statistical approach of the parton distributions for unpolarized and polarized both in Deep Inelastic Scattering and hadronic collisions. The statistical approach has been extended to the interesting situation where the PDF have, in addition to the usual Bjorken  $x$  dependence, an explicit  $k_T$  transverse momentum dependence (TMD) and this might be used in future calculations with no  $k_T$  integration. This is a very important topic, with a growing interest because it is now clear that several new phenomena are sensitive to TMD effects, possibly related to the orbital angular momentum component of the nucleon spin structure.

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## Detecting diffraction at the LHC

**Author:** Risto Orava<sup>1</sup>

**Co-authors:** J.W. Lamsa<sup>2</sup>; M.G. Ryskin<sup>3</sup>; V.K. Khoze<sup>4</sup>

<sup>1</sup> Helsinki Inst. of Physics and Univ. of Helsinki, CERN

<sup>2</sup> Iowa State Univ.

<sup>3</sup> Petersburg Nucl.Phys.Inst.

<sup>4</sup> IPPP, Dept. of Physics, Durham Univ.

**Corresponding Author:** risto.orava@cern.ch

**Abstract**

Photon bremsstrahlung is proposed to be used to identify elastic proton-proton interactions at the LHC. In addition to a measurement of the elastic pp cross section (assuming that the elastic slope is known), the bremsstrahlung photons will allow the evaluation of the total pp cross section, luminosity and to align the Zero Degree Calorimeters (ZDCs).

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## Hard exclusive vector meson leptonproduction at HERMES.

**Author:** Mayya Golembiovskaya<sup>1</sup>

<sup>1</sup> DESY, Zeuthen

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

The HERMES experiment at DESY, Hamburg collected a set of data on hard exclusive vector meson ( $\rho^0$ ,  $\phi$ ,  $\omega$ ) leptonproduction process using the 27.6 GeV HERA longitudinally polarized lepton beam and longitudinally and transversely polarized or unpolarized gas targets. Measurements of exclusive vector mesons production allow one to study the structure of the nucleon, since the process can be described in terms of Generalized Parton Distributions (GPDs). The azimuthal asymmetries measured in exclusive meson production in the HERMES experiment provide access to the information related to GPDs. Spin density matrix elements extracted at HERMES describe the distribution of final spin states of vector mesons. S-channel helicity conservation for  $\phi$  meson production is observed, whereas there are indications of violation from this hypothesis in case of  $\rho^0$  meson production. An overview of the HERMES results on exclusive vector mesons production processes is presented.

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## Gluon saturation in saturated environment

**Author:** Boris Kopeliovich<sup>1</sup>

**Co-authors:** Irina Potashnikova<sup>1</sup>; Ivan Schmidt<sup>2</sup>

<sup>1</sup> UTFSM

<sup>2</sup> UFSM

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

Broadening of gluons propagating through a nucleus is slowed down by the saturation effects in the target. This gives rise to an equation for the saturation scale which solution deviates from the leading order linear dependence on nuclear thickness  $T_A$  and becomes constant for very large  $T_A$ . The results for the saturation scale are similar to numerical solutions of the BK equation.

In the case of colliding nuclei the saturation effects lead to a mutual boosting of the saturation scales in both nuclei up to values higher than in pA collisions.

We derive reciprocity equations which show a considerable boosting effect, up to factor three, for the saturation scales at the energies of LHC.

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## Inclusive Measurements of Inelastic Lepton Scattering on Unpolarized Hydrogen and Deuterium Targets at 27.6 GeV.

**Author:** Lara De Nardo<sup>1</sup>

<sup>1</sup> Gent University

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



Results of the measurements of inclusive proton and deuteron inelastic scattering cross sections at the HERMES experiment are presented. The structure functions  $F_2^p$  and  $F_2^d$  are determined using a parameterization of existing data for the longitudinal-to-transverse virtual-photon absorption cross section ratio. The HERMES results provide data in the ranges  $0.006 \leq x \leq 0.9$  and  $0.1 \text{ GeV}^2 \leq Q^2 \leq 20 \text{ GeV}^2$  and are in agreement with existing world data in the region of overlap. In particular HERMES data cover the transient region between perturbative and non-perturbative regime in a so-far mostly unexplored kinematic region. The HERMES cross section measurements have been used, in conjunction to all other available world data, to perform fits to the total photon-proton cross section using the ALLM model. The deuteron-to-proton cross section ratio is also determined.

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## Diffraction on Nuclei: Effects of Nucleon-Nucleon Correlations and Inelastic Shadowing Within an Improved Glauber-Gribov Approach

**Author:** Claudio Ciofi Degli Atti<sup>1</sup>

**Co-authors:** Boris Kopeliovich<sup>2</sup>; Chiara Benedetta Mezzetti<sup>1</sup>; Irina Potashnikova<sup>2</sup>; Ivàn Schmidt<sup>2</sup>; Massimiliano Alvioli<sup>3</sup>

<sup>1</sup> *Department of Physics University of Perugia and INFN Sezione di Perugia, Italy*

<sup>2</sup> *Departamento de Física, Centro de Estudios Subatomicos, Universidad Tecnica Federico Santa Maria, and Centro Científico-Tecnológico de Valparaíso Casilla 110-V, Valparaíso, Chile*

<sup>3</sup> *INFN sezione di Perugia and ECT\* Trento, Italy*

**Corresponding Author:** claudio.ciofi@pg.infn.it

The cross sections for a variety of diffractive processes in proton-nucleus scattering, associated with large gaps in rapidity, are calculated [1] within an improved Glauber-Gribov theory, where the inelastic shadowing corrections are summed to all orders by employing the dipole representation [2] and the effects of nucleon-nucleon correlations, leading to a modification of the nuclear thickness function [3], are also taken into account. Numerical calculations are performed for the energies of the HERA-B experiment, and the RHIC and LHC colliders, and for several nuclei. It is found that whereas the Gribov corrections generally make nuclear matter more transparent, nucleon correlations act in the opposite direction and have important effects in various diffractive processes. The number of inelastic hadron-nucleus and nucleus-nucleus collisions  $n_{\text{coll}}(b)$  at impact parameter  $b$  [4], and its integral value  $N_{\text{coll}}$ , which are used to normalize the measured fractional cross section of a hard process, are also calculated within the same approach [5]. The results for gold-gold scattering at RHIC energies show that whereas Gribov inelastic corrections are negligible, nucleon-nucleon correlations appreciably affect the number of collisions.

[1] M. Alvioli, C. Ciofi degli Atti, B. Z. Kopeliovich, I. K. Potashnikova and I. Schmidt Phys. Rev. C81 (2010) 025204

[2] B. Z. Kopeliovich, I. K. Potashnikova and I. Schmidt Phys. Rev. C73 (2006) 034901

[3] M. Alvioli, C. Ciofi degli Atti, H. Morita, V. Palli Phys. Rev. C78 (2008) 031601(R).

[4] B. Z. Kopeliovich Phys. Rev. C68 (2003) 044906.

[5] C. Ciofi degli Atti, C. B. Mezzetti, B. Z. Kopeliovich, I. K. Potashnikova and I. Schmidt to appear.

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## The ALICE Experiment at LHC: Results and perspectives for diffractive physics. (for the ALICE Collaboration)

**Author:** Martin Poghosyan<sup>1</sup>

<sup>1</sup> *TO*

**Corresponding Author:** martin.poghosyan@to.infn.it

Proton–proton collisions are being studied with the ALICE detector not only as a benchmark for the comparison with heavy-ion reactions, but also as a means to study important aspects of pp physics in the new energy domain provided by the LHC. In this contribution ALICE results on general characteristics of pp interactions at  $\sqrt{s} = 0.9, 2.36$  and 7 TeV will be reported and their potential for diffractive physics presented.

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## A new detector array for Diffractive Physics in ALICE at the LHC

**Author:** Gerardo Herrera Corral<sup>1</sup>

<sup>1</sup> *Depto de Fisica, CINVESTAV*

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

A proposal to incorporate a new subdetector into the ALICE detector at the LHC is presented. The new system consists of four stations of scintillator pads at 20 and 55 meters from the interaction point on both sides. The system would extend the rapidity coverage increasing the sensitivity of the experiment to tag the diffractive rapidity gap.

The new system would enhance the capability of ALICE to address several subjects on diffractive physics as well as on photon induced physics in both proton-proton and peripheral ion-ion collisions.

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## Diffraction at the LHC: a model to merge soft and hard interactions

**Author:** Alan D. Martin<sup>1</sup>

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

abstract will be sent later

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## Standard Candle Processes at the Tevatron, LHC and RHIC

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

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

We discuss the ongoing studies by the Durham group on central exclusive production processes. Detailed comparison with the existing Tevatron data on quarkonium production are performed and predictions for RHIC and LHC are given.

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## Beyond cusp anomalous dimension from integrability

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

**Co-authors:** Davide Fioravanti <sup>2</sup>; Paolo Grinza <sup>3</sup>

<sup>1</sup> *CS*

<sup>2</sup> *BO*

<sup>3</sup> *Spagna*

**Corresponding Author:** rossi@cs.infn.it

We study the first sub-leading correction  $O(\ln s^0)$  to the cusp (minimal) anomalous dimension in the high spin expansion of finite twist operators in  $N=4$  SYM theory. This approximation is governed by a linear integral equation derived from Bethe Ansatz equations describing the ‘asymptotic’ spectrum of the dilatation operator. We emphasise how easily the weak coupling expansion can be obtained and then we pay particular attention to the strong coupling regime, showing agreement and predictions in comparison with the string expansion. Finally, speculations on the ‘universal’ part (upon subtracting the collinear anomalous dimension) are brought forward.

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## Diffraction and central exclusive production at ATLAS

**Author:** Marek Tasevsky<sup>1</sup>

<sup>1</sup> *Institute of Physics of ASCR, Prague*

**Corresponding Author:** marek.tasevsky@cern.ch

Diffraction physics program for the ATLAS experiment is discussed with emphasis on the Central Exclusive production. While making up a large part of the total proton-proton cross section, the experimental definition of diffractive processes is still under discussion. At low luminosities, a L1 trigger based on requiring rapidity gaps can be used, while at high luminosities, the use of proton taggers proposed to be placed at 220 m and 420 m from the interaction point is foreseen. Some first ATLAS results with candidates of diffractive events are presented and an outlook of other possible diffractive measurements is discussed.

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## Soft color screening effects in diffractive DIS

**Author:** Roman Pasechnik<sup>1</sup>

**Co-authors:** Gunnar Ingelman <sup>1</sup>; Rikard Enberg <sup>1</sup>

<sup>1</sup> *Uppsala University*

**Corresponding Author:** roman.pasechnik@fysast.uu.se

We construct a QCD-based model where soft gluon rescattering between final state partons in deep inelastic scattering leads to events with large rapidity gaps and a leading proton. The model successfully describes the precise HERA data on the diffractive deep inelastic structure function in the whole available kinematical range. Further developments and applications of the model are discussed.

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## Novel effects in J/Psi production in Nuclei

**Author:** Ivan Schmidt<sup>1</sup>

<sup>1</sup> *Universidad Tecnica Federico Santa Maria, Valparaiso, Chile*

**Corresponding Author:** ivan.schmidt@usm.cl

Colliding nuclei consist of nucleons with a shifted scale, which makes such a medium more opaque for dipoles. Therefore J/Psi will be more suppressed than predicts a simple extrapolation from pA to AA. Another effect is an enhanced color transparency. A ccbar dipole propagates simultaneously through both colliding nuclei. Due to color filtering one nucleus absorbs dipoles of larger size, and this make the other nucleus more transparent (compared with that in pA) for such small dipoles which survived in the first nucleus.

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## Overview of the Latest Results in Heavy Ion Physics from the PHENIX Detector at RHIC

**Author:** Senta Greene<sup>1</sup>

<sup>1</sup> *Vanderbilt*

**Corresponding Author:** senta.v.greene@vanderbilt.edu

One of the overarching goals of the experimental program at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory is an exploration of the production and properties of the hot and dense matter produced in high energy heavy ion collisions. In this talk, I present a selection of the latest results from the heavy ion program from the PHENIX collaboration at RHIC.

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## DIS and SIDIS at Jefferson Lab

**Author:** Sebastian Kuhn<sup>1</sup>

<sup>1</sup> *Old Dominion University*

**Corresponding Author:** skuhn@odu.edu

Jefferson Lab with its 6 GeV continuous electron beam of high luminosity and high polarization has taken a large set of data on electron scattering from (polarized and unpolarized) nucleon targets, covering DIS at moderate  $Q^2$  and high  $x$  as well as the transition region where hadronic effects become important (higher twist and resonance excitation contributions to the cross section). Using the large coverage of the CEBAF Large Acceptance Spectrometer (CLAS) in Hall B as well as multi-spectrometer set ups in Halls A and C, both inclusive and semi-inclusive channels have been measured, and some more experiments are still scheduled before the end of the 6 GeV era. The energy upgrade to 11-12 GeV will give us access to a much larger kinematic range and even higher precision in the near future.

In my talk, I will give an overview of the DIS and SIDIS program at Jefferson Lab and present selected results.

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## Meson spectroscopy in diffractive dissociation of high-energetic pions at COMPASS

**Author:** Jan Friedrich<sup>1</sup>

**Co-author:** for the COMPASS collaboration<sup>2</sup>

<sup>1</sup> *Physik Department E18, Technische Universität München*

<sup>2</sup> *CERN*

**Corresponding Author:** jan.friedrich@ph.tum.de

COMPASS at CERN uses hadron and muon beams with up to 200 GeV/c momentum, produced from the SPS proton beam, for investigations in hadron structure and spectroscopy.

From a pilot run with a 190 GeV/c pion beam on a lead target, various results will be presented, including the observation of the spin-exotic  $\pi_1(1600)$  resonance in the momentum transfer region  $0.3 < t' / (\text{GeV}/c)^2 < 1$ . Furthermore, in the low- $t'$  region interference of photon-exchange and strong production of the  $a_2(1320)$  resonance is observed, revealing the different nature of the two interactions.

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## Spin physics at Electron Ion Collider

**Author:** Alexey Prokudin<sup>1</sup>

<sup>1</sup> *JLab*

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

Future facility, Electron Ion Collider, will provide a unique opportunity to reveal three dimensional structure of the proton. The spin structure of the proton can be described by 8 Transverse Momentum Dependent distribution functions at leading twist. Properties of TMDs, EIC measurements and prospects are discussed.

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## Hadron spectroscopy in diffractive and central production processes at COMPASS

**Author:** Prometeusz Jasinski<sup>1</sup>

<sup>1</sup> *Institut für Kernphysik, Mainz*

**Corresponding Author:** jasinski@kph.uni-mainz.de

COMPASS is a fixed target experiment using secondary high-energetic hadron beams provided by the CERN SPS. In 2008 and 2009, a large amount of data has been collected with a 190 GeV/c pion beam for the investigation of the hadron spectrum in diffractive and central production processes.

A big variety of observed final states, including  $\pi\pi\pi$ ,  $\pi\pi^0\pi^0$ ,  $\pi\eta\eta$ ,  $\pi K_s K_s$ ,  $\pi K K$ ,  $K\pi\pi$ , and centrally produced  $4\pi$ , is presented. The potential for systematic spectroscopic studies especially concerning the existence and nature of spin-exotic, hybrid and glueball states is revealed.

In addition, the first results from the data set collected with a proton beam in 2009 will be presented. These data indicate the potential of COMPASS in the field of baryon spectroscopy.

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## Description of high-mass diffraction data in the framework of Gribov's Reggeon calculus.

**Author:** Martin Poghosyan<sup>1</sup>

**Co-author:** Alexei Kaidalov<sup>2</sup>

<sup>1</sup> *TO*

<sup>2</sup> *ITEP*

A model, based on Gribov's Reggeon calculus, is proposed and applied to processes of soft diffraction in hadronic interactions at high energies. It is shown that by accounting for absorptive corrections for all legs of triple-Regge and loop diagrams a good description of available experimental data on soft diffraction can be obtained in the energy range from ISR, FNAL to Tevatron (from  $P_{lab} = 65$  GeV/c to  $\sqrt{s} = 1800$  GeV). It is worth to emphasize that such a detailed description of inclusive diffraction in this broad region of energies is achieved for the first time.

We have observed that available data on inclusive spectra of intact (anti-)proton at single-diffractive interaction can be equivalently well described with and without accounting the interference terms. Nevertheless, there is a deviation between these two scenarios at the extrapolation to low-masses and that is ~40% at masses of the diffracted system  $M=10$  GeV/c<sup>2</sup>.

Incorporating this model with the Model of Quark-Gluon Strings, a good description of available SppS data on spectra of particles produced in proton-antiproton single-diffractive dissociation process is obtained in a parameter-free way.

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## Multivariate techniques for identifying diffractive interactions at the LHC

**Authors:** Eric Malmi<sup>1</sup>; Mikael Kuusela<sup>1</sup>; Risto Orava<sup>1</sup>; Tommi Vatanen<sup>1</sup>

**Co-authors:** Jerry W. Läsä<sup>1</sup>; Petteri Mehtälä<sup>1</sup>

<sup>1</sup> *Helsinki Institute of Physics*

**Corresponding Author:** mikael.kuusela@cern.ch

Close to one half of the LHC events are expected to be due to elastic or inelastic diffractive scattering. Still, predictions based on extrapolations of experimental data at lower energies differ by large factors in estimating the relative rate of diffractive event categories at the LHC energies.

Measurement of inelastic activity, such as multiplicity and energy flows, in forward and central detector systems can be used to efficiently classify proton–proton collisions. In combination with a powerful multivariate classification algorithm, the measurements will allow the first estimates of the single diffractive, double diffractive, central diffractive and non-diffractive cross sections at the LHC. With such a multivariate approach, one is not dependent on any specific rapidity gap definition of diffraction. Instead, optimal characteristics of each event class are found automatically while training the algorithms with Monte Carlo data.

In this talk, we present two different approaches for an event-by-event classification of forward physics processes at the LHC. We first show that hard classification where each event is unambiguously assigned to a single physics process can efficiently identify diffraction within a large sample of simulated proton–proton scattering events. We compare the performance of neural networks, gene expression programming and support vector machines in hard classification and show that neural networks are able to identify diffraction with the highest accuracy.

In the second part of the talk, we develop a soft classifier for diffraction. In this scheme, each event is assigned to a given class with a certain probability. The estimated class probabilities can then be used to weigh event contributions to physical observables. This approach is more consistent with probabilistic quantum mechanics and ensures the correct treatment of events lying in areas of the data space where different classes are overlapping.

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## Central Diffraction in ALICE

**Author:** Rainer Schicker<sup>1</sup>

<sup>1</sup> *Phys. Inst., University Heidelberg*

**Corresponding Author:** schicker@physi.uni-heidelberg.de

The abstract is under review by ALICE Conference Committee, I will send when approved

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## Transverse momentum distributions inside the nucleon from lattice QCD

**Author:** Bernhard Musch<sup>1</sup>

**Co-authors:** Andreas Schäfer<sup>2</sup>; John Negele<sup>3</sup>; Philipp Hägler<sup>4</sup>

<sup>1</sup> *Jefferson Lab*

<sup>2</sup> *Universität Regensburg, Germany*

<sup>3</sup> *Massachusetts Institute of Technology, MA, USA*

<sup>4</sup> *Technische Universität München*

**Corresponding Author:** bmusch@jlab.org

Transverse momentum dependent parton distribution functions (TMDs) provide a framework to study the spin-dependent motion of quarks inside the nucleon. They are relevant for our understanding of azimuthal asymmetries in, e.g., semi-inclusive DIS. We present lattice calculations of TMDs based on spatially separated quark operators connected by a gauge link. Studies with straight gauge links reveal, e.g., visible dipole deformations of the quark density in the transverse momentum plane. Progress towards TMDs more suitable for the description of experimental processes and, in particular, single-spin asymmetries can be made with a staple shaped link geometry.

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## Diffraction News from CDF

**Author:** Konstantin Goulianos<sup>1</sup>

<sup>1</sup> *The Rockefeller University*

**Corresponding Author:** dino@rockefeller.edu

Results on diffractive W and Z production and an update on the diffractive structure function extracted from dijet production are presented and compared with previously reported results and with expectations.

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## Physics with Forward Neutrons

**Author:** sebastian white<sup>1</sup>

<sup>1</sup> *Brookhaven National Lab*

**Corresponding Author:** swhite@bnl.gov

The measurement of forward neutrons and photons is a common feature of all RHIC experiments. It was motivated by the role of forward neutrons in event characterization and in accessing diffractive phenomena in nuclear collisions.

In pp collisions at RHIC measurement of forward neutrons has been useful:

since ~40% of the time the leading baryon in a non-diffractive collision is a neutron, measurement of neutron  $x_F$  between 0.2 and 1.0 is an important complement to measurements of protons at colliders- typically in a very limited range of  $x_F$ .

I will also present results from first operation of the ATLAS zero degree calorimeter which is now extending this physics to  $\sqrt{s}=7$  TeV.

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## ”PHENIX results on spin dependent neutron asymmetry”

**Author:** sebastian white<sup>1</sup>

<sup>1</sup> *Brookhaven National Lab*

**Corresponding Author:** swhite@bnl.gov

PHENIX has observed a very large spin dependent asymmetry in forward neutron production in pp collisions at several energies up



to  $\sqrt{s} = 500$  GeV. We present results on beam energy and  $x_F$  dependence of this asymmetry and discuss the large discrepancy with currently available calculations of this effect.

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## Universality of Factorization Breaking in Diffraction

**Author:** Konstantin Goulianos<sup>1</sup>

<sup>1</sup> *The Rockefeller University*

**Corresponding Author:** dino@rockefeller.edu

Results on factorization breaking in soft and hard hadron-hadron collisions, photo-production and deep inelastic scattering are shown to exhibit a universal behavior in a (renormalization) model where diffraction is mediated by a saturated colorless exchange with vacuum quantum numbers. Formulas for cross sections and final state event properties are obtained, and a scheme is proposed for implementing them into a simulation that can be extrapolated to LHC energies and beyond.

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## Forward jet production at the Large Hadron Collider

**Author:** Krzysztof Kutak<sup>1</sup>

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

We will discuss phenomena of production of forward jet at the LHC. After brief introduction to high energy factorization we will present matrix elements relevant for production of forward jets focusing on their high energy behavior and dependence on transversal momentum of off shell gluon. We will also investigate effects of angular ordered parton shower and its interplay with matrix elements. Finally phenomenological results which are  $p_T$  spectra of produced jets and rapidity dependence will be presented.

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## SANE of Jefferson Lab: Spin Asymmetries on the Nucleon Experiment

**Author:** Abdellah Ahmidouch<sup>1</sup>

<sup>1</sup> *North Carolina A&T State University*

**Corresponding Author:** abdellah@ncat.edu

The Spin Asymmetry on the Nucleon Experiment (SANE) at Jefferson Lab measures spin observables  $A_{1p}$ ,  $A_{2p}$  and structure functions  $g_{1p}$  and  $g_{2p}$  over a broad range of Bjorken scaling variable  $x$  from 0.3 to 0.8, for four-momentum transfers from 2.5 GeV<sup>2</sup> to 6.5 GeV<sup>2</sup>. Inclusive double spin asymmetries were measured by scattering 4.7 and 5.9-GeV longitudinally polarized electron beam off a dynamically polarized ammonia target, in both parallel and transverse configuration. Scattered electrons were detected using the Big Electron Telescope Array (BETA), a novel non-magnetic detector array with a 194-msr acceptance. The experiment ran January through March 2009. This paper

presents the physics motivation for the experiment, the expected results, kinematics coverage, detector performance and calibrations, quality of the collected data, and the latest status of the ongoing data analysis.

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## Scaling properties in deep inelastic scattering

**Author:** David Salek<sup>1</sup>

<sup>1</sup> *IPNP, Charles University, Prague*

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

We study the scaling properties in deep inelastic scattering using the most recent combined structure function data F2 from the H1 and ZEUS collaborations. We also perform a direct fit to the F2 data inspired by the scaling properties.

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## Latest results on transverse momentum dependent distribution functions at HERMES

**Author:** Achim Hillenbrand<sup>1</sup>

<sup>1</sup> *DESY*

**Corresponding Author:** achim.hillenbrand@desy.de

The analysis of transverse momentum dependent quark distribution functions (TMDs), which are related to spin orbit correlations of the quarks within the nucleon, is an active field of research.

One way to gather information about TMDs on the experimental side is the measurement of azimuthal single-spin asymmetries (SSA)  $A^h_{UT}$  in semi-inclusive deep-inelastic scattering (SIDIS) of longitudinally polarized (L) electrons and positrons off a transversely polarized (T) proton target. The lepton beam can be considered unpolarized (U) as the recorded data is balanced with respect to the beam helicity states. A Fourier analysis of these asymmetries yields components which can be interpreted as convolutions in transverse momentum space of transverse-momentum dependent distribution and fragmentation functions. Two of these components provide leading-twist signals for the naive time reversal odd Sivers functions and the chiral-odd transversity function. The final results on these single-spin asymmetry amplitudes are presented.

Furthermore, azimuthal single-spin asymmetries  $A^h_{UT}$  have been extracted for the first time from inclusive hadron production using the same beam and target setup. These measurements are complementary to the well known large left-right asymmetries  $A_N$  in transversely polarized proton-proton scattering, but represent a much cleaner channel, involving just one proton quark field. The measurement of these asymmetries provide a test for the validity of TMD factorization, which is largely accepted for the SIDIS case involving two scales (small  $p_t$  and large  $Q^2$ ), but is still under debate for processes involving one large scale ( $p_t$ ), like inclusive DIS.

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## Overview of the PHENIX Longitudinal spin program at RHIC

**Author:** Murad Sarsour<sup>1</sup>

<sup>1</sup> *Georgia State University*

**Corresponding Author:** murad.sarsour@gmail.com

The polarized p+p collisions at RHIC, while complementary to deep inelastic lepton scattering experiments, offer distinct advantages for the determination of the helicity preferences of gluons. The PHENIX experiment has been measuring the double longitudinal spin asymmetry of several inclusive probes to understand the gluon polarization in the allowed kinematic range. A brief overview is given of results to date and planned future directions.

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## Forward collisions and spin effects in evaluating amplitudes

**Author:** Nigel Buttimore<sup>1</sup>

<sup>1</sup> *Trinity College Dublin*

**Corresponding Author:** nigel.buttimore@tcd.ie

Total cross sections and the phases of forward collision amplitudes form part of the early studies when a new energy window becomes available as is provided by the Large Hadron Collider. Enhancement of the forward elastic differential cross section above that expected from estimates of dispersion and optical theorem values may result from the presence of hadronic spin dependence in addition to effects induced by vacuum polarization contributions to the photon propagator. The elastic scattering of protons and ions at small angles is important in the evaluation of the luminosities of the corresponding incident beams and invites detailed examination. Polarization measurements taken at a number of high energies have yielded information on the extent of spin effects in hadronic scattering, particularly at the low momentum transfers related to diffraction.

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## Pomeron Induced Physics at LHC Energies and Above

**Author:** URI MAOR<sup>1</sup>

<sup>1</sup> *Tel Aviv University*

**Corresponding Author:** maor@post.tau.ac.il

Updated formulations of the soft Pomeron, in which  $s$  and  $t$  channel unitarity screenings are included, are reviewed.

The consequent soft total, elastic, diffractive and inclusive cross sections are explored.

Calculations of the gap survival probability, which is critical to hard diffractive processes, are presented.

The interplay between theory and data analysis is discussed.

A critical assessment of predictions and simulations based on ISR-Tevatron data concludes this presentation.

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## Modelling pion and proton total cross-sections at LHC}

**Author:** Yogendra Srivastava<sup>1</sup>

**Co-authors:** Agnes Grau<sup>2</sup>; Giulia Pancheri<sup>3</sup>; Olga Shekhovstova<sup>3</sup>

<sup>1</sup> *University of Perugia & INFN*

<sup>2</sup> *University of Granada*

<sup>3</sup> *INFN - LNF*

To settle the question whether the growth with energy is universal for different hadronic total cross-sections, we present results from theoretical models for  $\pi p$  and  $(pp, p\bar{p})$  total cross-sections obtained with the same input. We show that present and planned experiments at LHC can differentiate between different models, all of which are consistent with presently available (lower energy) data. This study is also relevant for the analysis of those very high energy cosmic ray data which require reliable  $\pi p$  total cross-sections as seeds. A preliminary study of the total  $\pi\pi$  cross-sections is also made.

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## **Gluon contribution to the nucleon spin and the role of Orbital Angular Momentum**

**Author:** Firooz Arash<sup>1</sup>

<sup>1</sup> *Tafresh University, Iran*

We have calculated  $\Delta E_{1g}$  over  $g$  in the context of valon representation of hadrons and have shown that although it may be small, the gluon contribution to the nucleon spin can be sizable. The calculation is done for every kinematics that there is data, including the very recent releases from HERMES and COMPASS collaborations. It is shown that the first moment of gluon polarization in nucleon is large and grows with  $Q^2$ . To compensate this growth it is necessary that to have a large and negative value for the orbital angular momentum of partons.

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## **Effective actions for high energy scattering in QCD and in gravity**

**Author:** Lev Lipatov<sup>1</sup>

<sup>1</sup> *PNPI St. Petersburg*

I remind the gauge invariant action for the reggeized gluon interactions. It allows one to construct next-to-leading corrections to the BFKL and BKP equations. A similar general covariant action for the reggeized graviton interactions in the Einstein gravity is derived. The known results for the reggeon trajectory and reggeon-graviton vertices are reproduced. Other applications of this action are discussed

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## **PHENIX Measurement of Parity-Violating Single Spin Asymmetry in W Production in p+p Collisions at 500 GeV**

**Author:** Stephen Pate<sup>1</sup>

<sup>1</sup> *New Mexico State University*

**Corresponding Author:** pate@nmsu.edu

The flavor-separated polarized parton distribution functions for light quarks and anti-quarks in the proton can be studied in the production of W bosons in p+p collisions. The Ws are produced in processes like  $u + \bar{d} \rightarrow W^+$  and  $\bar{u} + d \rightarrow W^-$  and we observe the lepton (an electron or muon) from the decay channel  $W^+ \rightarrow l^+ \nu$ . The electron energy spectrum from W decays measured with an integrated luminosity of approximately  $10 \text{ pb}^{-1}$  will be shown, with a measurement of the electron single spin asymmetry in central rapidity.

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## Fluctuations, Saturation, and Diffraction with DIPSY

**Author:** Christoffer Flensburg<sup>1</sup>

<sup>1</sup> *Lund University*

**Corresponding Author:** christoffer.flensburg@thep.lu.se

Diffraction is usually described by the Good-Walker formalism for low masses, and by the triple-Regge formalism for high masses. In the Good-Walker formalism the cross section is determined by the fluctuations in the interaction. By taking the fluctuations in the BFKL ladder into account, it is possible to describe both low and high mass excitation by the Good-Walker mechanism. In high energy  $pp$  collisions the fluctuations are strongly suppressed by saturation, which implies that pomeron exchange does not factorise between DIS and  $pp$  collisions. The Dipole Cascade Model reproduces the expected triple-Regge form for the bare pomeron, and the triple-pomeron coupling can be estimated.

Some notes will also be made on exclusive final states in this model.

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## Higher twist effects in small x neutrino DIS

**Author:** Vladimir Zoller<sup>1</sup>

<sup>1</sup> *ITEP, Moscow*

**Corresponding Author:** zoller@itep.ru

The non-conservation of charmed-strange current in the neutrino deep inelastic scattering strongly affects the longitudinal structure function,  $F_L$ , at small values of Bjorken  $x$ . The corresponding correction to  $F_L$  is a higher twist effect enhanced at small- $x$  by the rapidly growing gluon density factor. As a result, the component of  $F_L$  induced by the charmed-strange current prevails over the light-quark component and dominates  $F_L = F_L^{cs} + F_L^{ud}$  at  $x \lesssim 0.01$  and  $Q^2 \sim m_c^2$ . The color dipole BFKL analysis clarifies the physics behind the phenomenon and provides a quantitative estimate of the effect.

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## CMS results on diffraction

**Author:** Antonio Vilela Pereira<sup>1</sup>

<sup>1</sup> *TO*

The observation of inclusive diffraction at LHC with the CMS detector at  $\sqrt{s}=900, 2360$  and  $7000$  GeV is presented, along with a comparison of the data with the predictions of the PYTHIA and PHOJET generators.

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## Forward physics at CMS

**Author:** Benoit Roland<sup>1</sup>

<sup>1</sup> *CERN*

Studies of the forward processes are important tests of the standard model and inputs for Monte Carlo tuning. A measurement of the energy flow in the forward pseudorapidity region of CMS,  $3.15 < |\eta| < 4.9$ , is presented for 3 values of the centre-of-mass energy  $\sqrt{s} = 0.9$  TeV, 2.36 TeV and 7 TeV. The forward energy flow is measured for Minimum Bias events and for events with a central dijet system whose transverse energy provides a hard scale. The energy flow is compared to various Monte Carlo models with different multiparton interaction schemes. A study of the forward jets in the pseudorapidity range  $3.2 < |\eta| < 4.7$  is presented for  $\sqrt{s} = 7$  TeV.

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## Diffraction results from D0

**Author:** Christophe Royon Royon<sup>1</sup>

<sup>1</sup> *IRFU-SPP, CEA Saclay*

to be advised

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## Diffraction with an EIC

**Author:** Salvatore Fazio<sup>1</sup>

<sup>1</sup> *BNL*

Overview of the status of art of the diffractive physics program with the future EIC/eRHIC machine will be given. eRHIC is a machine designed to accelerate an electron beam with energies ranging up to 20 (30) GeV to collide with a hadron beam (protons, nuclei) at an energy which can be varied up to 325 GeV. The high luminosity of the machine, expected in the order of  $10^{34}$  cm<sup>-2</sup> s<sup>-2</sup>, will open the opportunity for very high precision measurements of a large variety of diffractive events.

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## Recent progress in theory of the transverse momentum parton densities

**Author:** Igor Cherednikov<sup>1</sup>

<sup>1</sup> *INFN Cosenza*

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## Results on transverse spin asymmetries in the polarized proton-proton elastic scattering in the CNI region at STAR

**Author:** Dmitry Svirida<sup>1</sup>

<sup>1</sup> *ITEP*

To be advised

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## Jets and heavy flavors at HERA

**Author:** Ramoona Shehzadi<sup>1</sup>

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

To be advised

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## Study of non-collinear parton dynamics in the prompt photon photoproduction at HERA

**Author:** Nikolai Zotov<sup>1</sup>

<sup>1</sup> *SINP*

We investigate the prompt photon photoproduction at HERA within the framework of  $k_T$ -factorization QCD approach.

Our consideration is based on the off-shell matrix elements for the underlying partonic subprocesses. The unintegrated parton densities in a proton and in a photon are determined using the Kimber-Martin-Ryskin (KMR) prescription.

Additionally, we use the CCFM-evolved unintegrated gluon as well as valence and sea quark distributions in a proton.

A conservative error analysis is performed.

The theoretical results are compared with the recent experimental data taken by the H1 and ZEUS

collaborations.

We study also the specific kinematical properties of the photon-jet system which are strongly sensitive to the transverse momentum of incoming partons.

Using the KMR scheme, the contribution from the quarks emerging from the earlier steps of the parton evolution is estimated and found to be of 15 – 20\% approximately.

See arXiv:0907.3303 [hep-ph], PR D81 (2010) 094027

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## **A Monte Carlo study of finite top mass effects on inclusive Higgs production via gluon fusion**

**Author:** Vassilis Pandis<sup>1</sup>

<sup>1</sup> *DESY*

To be advised