

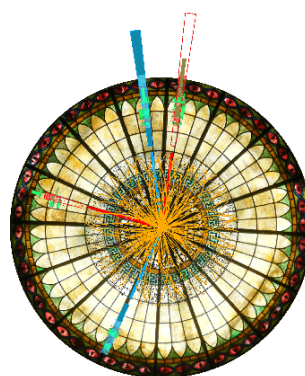
# DIS 2015 - XXIII. International Workshop on Deep-Inelastic Scattering and Related Subjects

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**DIS 2015**

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## Book of Abstracts



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## WG6 Spin Physics / 12

**Transverse single-spin asymmetries  $A_{UT}^{\sin\phi_S}$  and  $A_{UT}^{\sin(2\phi_h-\phi_S)}$  in SIDIS****Author:** Wenjuan Mao<sup>1</sup>**Co-authors:** Bo-Qiang Ma<sup>2</sup>; Zhun Lu<sup>1</sup><sup>1</sup> Southeast University<sup>2</sup> Peking University**Corresponding Author:** wjmiao@seu.edu.cn

We study the single-spin asymmetries with the  $\sin\phi_S$  and  $\sin(2\phi_h - \phi_S)$  angular dependencies of pion production in semi-inclusive deep inelastic scattering off a transversely polarized proton target. We investigate the role of the distributions  $f_T$ ,  $h_T$  and  $h_T^\perp$  in the  $\sin\phi_S$  asymmetry, as well as the role of the distributions  $f_T^\perp$ ,  $h_T$  and  $h_T^\perp$  in the  $\sin(2\phi_h - \phi_S)$  asymmetry. We calculate the four twist-3 distributions  $f_T(x, \boldsymbol{k}_T^2)$ ,  $f_T^\perp(x, \boldsymbol{k}_T^2)$ ,  $h_T(x, \boldsymbol{k}_T^2)$ , and  $h_T^\perp(x, \boldsymbol{k}_T^2)$  in a spectator-diquark model including vector diquarks. With the model results on these TMD distributions, for the first time we predict the two corresponding asymmetries for  $\pi^+$ ,  $\pi^-$  and  $\pi^0$  produced off the proton target at the kinematics of HERMES, JLab, and COMPASS.

## WG1 Structure Functions and Parton Densities / 15

**Charge densities in impact parameter and transverse coordinate space****Author:** Harleen Dahiya<sup>1</sup>**Co-author:** Kumar Narinder<sup>1</sup><sup>1</sup> Dr. B.R. Ambedkar National Institute of Technology**Corresponding Author:** dahiyah@nitj.ac.in

Electromagnetic form factors obtained from the overlap of light front wave functions (LFWFs) have been used to study the transverse densities of charge and magnetization. The calculations have been carried out to develop a relation between the charge distribution of the quarks inside nucleon in the transverse coordinate space as well as in the impact parameter space. The anomalous magnetization density of the nucleon has also been discussed.

## WG3+WG5 Joint Session / 17

**A New Method for Indirect Mass Measurements using the Integral Charge Asymmetry at the LHC****Author:** Steve Guy Muanza<sup>1</sup>**Co-author:** Thomas Clement Serre<sup>2</sup><sup>1</sup> CPPM, Aix-Marseille Université, CNRS/IN2P3 (FR)<sup>2</sup> Centre National de la Recherche Scientifique (FR)

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We propose a novel method for an indirect measurement of the mass of final states produced through charged current processes at the LHC. This method is based upon the process integral charge asymmetry. First, the theoretical prediction of the integral charge asymmetry and its related uncertainties are studied through parton level cross sections calculations. Then, the experimental extraction of the integral charge asymmetry of a given signal, in the presence of some background, is performed using particle level simulations. Process dependent templates enable to convert the measured integral charge asymmetry into an estimated mass of the charged final state. Finally, a combination of the experimental and the theoretical uncertainties determines the full uncertainty of the indirect mass measurement. This new method applies to all charged current processes at the LHC. In this study, we demonstrate its effectiveness at extracting the mass of the  $W$  boson, as a first step, and the sum of the masses of a chargino and a neutralino in case these supersymmetric particles are produced by pair, as a second step. Note that contrarily to most of the usual mass reconstruction techniques that are based upon the kinematics of the events final state, this method depends on the events initial state and mainly reflects the charge asymmetry of the colliding protons.

**WG4 QCD and Hadronic Final States / 19**

## On the resummation of non-global logarithms at finite $N_c$

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We calculate non-global logarithms at finite  $N_c$  for the hemisphere mass distribution in  $e^+e^- \rightarrow q\bar{q}$  at single logarithmic accuracy up to fifth order in the coupling constant. Our results indicate the possibility of resummation of these logarithms to all orders into an exponential form. We compare our findings to those reported in the literature at large  $N_c$  and find agreement. We also compare our results with numerical all-orders resummation at large  $N_c$  and discuss the importance of finite  $N_c$  corrections on the said distribution.

**WG4 QCD and Hadronic Final States / 20**

## Eikonal gluon radiation at finite- $N_c$ beyond 2-loops

**Author:** Kamel Khelifa-Kerfa<sup>1</sup>

**Co-author:** Yazid Delenda<sup>2</sup>

<sup>1</sup> *Université Hassiba Benbouali de Chlef*

<sup>2</sup> *Université Hadj Lakhdar - Batna*

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We present a general formalism for computing the matrix-elements squared for the emission of soft energy-ordered gluons to (theoretically) any order in perturbation theory at finite  $N_c$ . Our formalism is valid in the eikonal approximation. A Mathematica package is being developed for the automated calculation of all real/virtual eikonal squared-amplitudes necessary at a given order. For the purpose of illustration we show the explicit forms of the eikonal amplitudes up to the fifth order. In the large- $N_c$  limit our results coincide with those previously reported in literature.



## WG6 Spin Physics / 21

**Boundary terms in the decomposition of nucleon spin****Author:** Peter Lowdon<sup>1</sup><sup>1</sup> *University of Zurich*

The decomposition of nucleon spin into spin and orbital angular momentum contributions from partons is revisited in the context of quantum field theory. It is shown that commonly used decompositions rely on classical-type arguments for their justification, and that these arguments may no longer hold in the full quantum theory, in particular with respect to the treatment of boundary terms. The role of these terms in the construction of quark-gluon decompositions of the QCD angular momentum operator is investigated, casting doubt on the applicability of certain identifications of quark and gluon contributions to the nucleon spin [arXiv:1408.3233].

## WG6 Spin Physics / 22

**Measurement of Collins Asymmetry at BESIII****Co-author:** Isabella Garzia<sup>1</sup><sup>1</sup> *INFN***Corresponding Author:** garzia@fe.infn.it

There has been increasing interest in understanding the spin phenomena in the nucleon, such as the transverse spin structure (the so-called transversity). The semi-inclusive observables in SIDIS experiments are only connected to the product of quark transversity distribution and the Collins fragmentation function (FF). An independent measurement of the Collins FFs in e+e- annihilation makes it possible to extract the transversity from single transverse spin asymmetries in SIDIS.

The Collins FF connects transverse quark spin with a measurable azimuthal asymmetry (the so-called Collins effect) in the yields of hadronic fragments along the initial quark's momentum. Collins effect has been studied in the Belle and BABAR experiments and non-zero Collins asymmetries have been observed. However, Belle and BABAR run at high Q (~10 GeV) region, and existing SIDIS experiments mostly run at low Q region. Hence, energy evolution from high Q to low Q is not trivial and its theoretical treatment needs to be guaranteed. Direct measurement of Collins function in low Q region will provide important test.

In the BESIII experiment, we explore Double Collins Asymmetries (DCA) by looking at the two back-to-back charged pions. BEIII experiment is an electron-positron collider running at  $2 < Q < 4.6$  GeV energy region, which has similar energy coverage with the SIDIS experiments. This analysis is carried out based on ~65/pb data at Q=3.65 GeV and will provide the first measurement of Collins asymmetry at low Q. This analysis results will be reported in the DIS2015 conference.

## WG1 Structure Functions and Parton Densities / 23

**Progress in CT PDF analysis****Author:** C.-P. Yuan<sup>1</sup>**Co-author:** Pavel Nadolsky<sup>2</sup><sup>1</sup> *Michigan State University*<sup>2</sup> *Southern Methodist University*

**Corresponding Authors:** yuan@pa.msu.edu, nadolsky@smu.edu

I review progress in the global PDF analysis by the CTEQ-TEA group.

#### WG4 QCD and Hadronic Final States / 24

### DIS Event Shape at N<sup>3</sup>LL

**Author:** Daekyoung Kang<sup>1</sup>

**Co-authors:** Christopher Lee<sup>1</sup>; Iain Stewart<sup>2</sup>

<sup>1</sup> LANL

<sup>2</sup> MIT

Event shapes provide a key method of measuring jets in DIS. This was done successfully by H1 and ZEUS and compared with theoretical calculations with next-to-leading-logarithmic (NLL) resummation.

We will present a high precision calculation of a event shape called DIS thrust, with next-to-next-to-next-to-leading-logarithmic resummation and a rigorous treatment of hadronization corrections. Perturbative resummation uncertainties in the cross section are reduced to the 2% level for a significant region of the HERA phase space in  $x$  and  $Q$ , thus allowing for new accurate measurements of  $\alpha_s(m_Z)$ .

#### WG5 Heavy Flavours / 25

### AdS/QCD predictions for semileptonic and rare B decays to $\rho$ and $K^*$ vector mesons.

**Author:** Mohammad Ahmady<sup>1</sup>

**Co-author:** Ruben Sandapen<sup>2</sup>

<sup>1</sup> Mount Allison University

<sup>2</sup> Université de Moncton

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We use the light front wavefunction for meson bound state obtained from holographic anti-de Sitter/chromodynamics to calculate the distribution amplitudes (DAs) for  $\rho$  and  $K^*$  vector mesons. Consequently, these DAs are utilized to compute the form factors for  $B \rightarrow \rho, K^*$  transition via light cone sum rules. Our predictions for semileptonic and rare B decays are compared with experimental measurements.

#### WG1 Structure Functions and Parton Densities / 26

### NNPDF3.0: Parton distributions for the LHC Run II

**Author:** Christopher Deans<sup>1</sup>

<sup>1</sup> University of Edinburgh

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I will present NNPDF3.0, the first set of parton distributions determined with a methodology validated by a closure test. NNPDF3.0 uses a global dataset including HERA-II deep-inelastic inclusive cross-sections, the combined HERA charm data, jet production from ATLAS and CMS, vector boson rapidity and transverse momentum distributions from ATLAS, CMS and LHCb,  $W + c$  data from CMS and top quark pair production total cross sections from ATLAS and CMS. Results are based on LO, NLO and NNLO QCD theory and also include electroweak corrections. To validate our methodology, I will show that PDFs determined from pseudo-data generated from a known underlying law correctly reproduce the statistical distributions expected on the basis of the assumed experimental uncertainties. I will also explore some of the phenomenological implications of our results for the upcoming 13 TeV Run of the LHC, in particular for Higgs production cross-sections.

**WG4 QCD and Hadronic Final States / 27**

## Measurement of Multijet Production in ep Collisions at High $Q^2$ and Determination of the Strong Coupling $\alpha_s$

**Author:** Collaboration H1<sup>1</sup>

**Co-authors:** Karin Daum<sup>2</sup>; Stefan Schmitt<sup>3</sup>

<sup>1</sup> DESY

<sup>2</sup> University of Wuppertal/DESY

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Inclusive jet, dijet and trijet differential cross sections are measured in neutral current deep-inelastic scattering for exchanged boson virtualities  $150 < Q^2 < 15000 \text{ GeV}^2$  using the H1 detector at HERA. The data were taken in the years 2003 to 2007 and correspond to an integrated luminosity of  $351 \text{ pb}^{-1}$ . Double differential Jet cross sections are obtained using a regularised unfolding procedure. They are presented as a function of  $Q^2$  and the transverse momentum of the jet,  $P_{T^{\text{jet}}}$ , and as a function of  $Q^2$  and the proton's longitudinal momentum fraction,  $X_i$ , carried by the parton participating in the hard interaction. In addition normalised double differential jet cross sections are measured as the ratio of the jet cross sections to the inclusive neutral current cross sections in the respective  $Q^2$  bins of the jet measurements. Compared to earlier work, the measurements benefit from an improved reconstruction and calibration of the hadronic final state. The cross sections are compared to perturbative QCD calculations in next-to-leading order and are used to determine the running coupling and the value of the strong coupling constant as  $\alpha_s(M_Z) = 0.1165(8)_{\text{exp}}(38)_{\text{pdf,theo}}$ .

**WG2 Small-x, Diffraction and Vector Mesons / 28**

## Measurement of Dijet Production in Diffractive Deep-Inelastic ep Scattering at HERA

**Author:** Stefan Schmitt<sup>1</sup>

**Co-author:** Karin Daum<sup>2</sup>

<sup>1</sup> Deutsches Elektronen-Synchrotron (DE)

<sup>2</sup> University of Wuppertal/DESY

**Corresponding Author:** stefan.schmitt@cern.ch

A measurement is presented of single- and double-differential dijet cross sections in diffractive deep-inelastic ep scattering at HERA using data collected by the H1 experiment corresponding to an integrated luminosity of  $290 \text{ pb}^{-1}$ . The investigated phase space is spanned by the photon virtuality in the range of  $4 < Q^2 < 100 \text{ GeV}^2$  and by the fractional proton longitudinal momentum loss  $x_{\text{pom}} < 0.03$ . The resulting cross sections are compared with next-to-leading order QCD predictions based on diffractive parton distribution functions and the value of the strong coupling constant is extracted.

**WG2 Small-x, Diffraction and Vector Mesons / 29**

## **Diffractive Dijet Production with a Leading Proton in ep Collisions at HERA**

**Author:** Stefan Schmitt<sup>1</sup>

**Co-author:** Karin Daum<sup>2</sup>

<sup>1</sup> *Deutsches Elektronen-Synchrotron (DE)*

<sup>2</sup> *University of Wuppertal/DESY*

**Corresponding Author:** stefan.schmitt@cern.ch

The cross section of the diffractive process  $e^+p \rightarrow e^+Xp$  is measured at a centre-of-mass energy of 318 GeV, where the system X contains at least two jets and the leading final state proton p is detected in the H1 Very Forward Proton Spectrometer. The measurement is performed in photoproduction with photon virtualities  $Q^2 < 2 \text{ GeV}^2$  and in deep-inelastic scattering with  $4 \text{ GeV}^2 < Q^2 < 80 \text{ GeV}^2$ . The results are compared to next-to-leading order QCD calculations based on diffractive parton distribution functions as extracted from measurements of inclusive cross sections in diffractive deep-inelastic scattering.

**WG2 Small-x, Diffraction and Vector Mesons / 30**

## **Azimuthal correlations in high-energy pp/pA collisions and anisotropic gluon distributions**

**Author:** Adrian Dumitru<sup>1</sup>

<sup>1</sup> *Baruch College (City University of New York)*

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Experiments at RHIC and the LHC have revealed anisotropic multi-particle azimuthal correlations in high multiplicity pp and pA collisions. These correlations are long range in rapidity (resp.  $\log 1/x$ ) and extend to semi-hard transverse momenta of several GeV. I discuss first steps towards understanding azimuthal correlations from small-x QCD, and the information they could provide about anisotropic gluon distributions at small x.

**WG7 Future experiments / 32**

## **The ATLAS Tile Calorimeter and its upgrades for the high luminosity LHC**

**Author:** Iouri Smirnov<sup>1</sup>

<sup>1</sup> *Northern Illinois University (US)*

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The Tile Calorimeter (TileCal) of the ATLAS experiment at the LHC is the hadronic calorimeter designed for energy reconstruction of hadrons, jets, tau-particles and missing transverse energy. A summary of performance results for TileCal using pp collisions from the LHC Run I will be presented. For Run 2, which will start this summer, the expected effects of increasing pile-up with rising luminosity will be discussed. For the high luminosity era a major upgrade of the TileCal electronics is planned, and the ongoing developments for on- and off-detector systems, together with expected performance characteristics, will be described.

## WG6 Spin Physics / 33

### TMD factorization and evolution at large $b_T$

**Author:** John Collins<sup>1</sup>

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In using transverse-momentum-dependent (TMD) parton densities and fragmentation functions, important non-perturbative information is at large transverse position  $b_T$ . This concerns both the TMD functions and their evolution. Fits to high energy data tend to predict too rapid evolution when extrapolated to low energies where larger values of  $b_T$  dominate. I summarize a new analysis of the issues. It results in a proposal for much weaker  $b_T$  dependence at large  $b_T$  for the evolution kernel, while preserving the accuracy of the existing fits. The results are particularly important for using transverse-spin-dependent functions like the Sivers function.

## WG3:Electroweak Physics and Beyond the Standard Model / 34

### Z and W production in the forward region

**Author:** Stefania Vecchi<sup>1</sup>

<sup>1</sup> *INFN Ferrara*

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The latest results on Z and W production measured by LHCb in the forward region are presented.

## WG2 Small-x, Diffraction and Vector Mesons / 35

### Central exclusive production measurements at LHCb

**Author:** Stefania Vecchi<sup>1</sup>

<sup>1</sup> INFN Ferrara

**Corresponding Author:** ronan.wallace@cern.ch

The recent LHCb results on central exclusive production are presented.

**WG5 Heavy Flavours / 40**

## Rare b and c decays at LHCb

**Authors:** Marcin Chrzaszcz<sup>1</sup>; Stefania Vecchi<sup>2</sup>

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<sup>2</sup> INFN Ferrara

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An overview of the latest LHCb results on rare b and c-hadron decays is presented

**WG2 Small-x, Diffraction and Vector Mesons / 43**

## Coulomb corrections to DIS off heavy nuclei

**Author:** Kirill Tuchin<sup>1</sup>

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I calculate the Coulomb corrections to the total and diffractive cross sections in DIS off heavy nuclei. I show that they violate the geometric scaling and have important phenomenological implications for a future EIC program.

**WG6 Spin Physics / 44**

## Singlet and non-singlet axial-vector form factors for the octet baryons.

**Author:** Harleen Dahiya<sup>1</sup>

**Co-author:** Monika Randhawa<sup>2</sup>

<sup>1</sup> Dr. B.R. Ambedkar National Institute of Technology

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The axial-vector form factors of the low lying octet baryons ( $N$ ,  $\Sigma$ ,  $\Xi$  and  $\Lambda$ ) have been studied for the implications of chiral symmetry breaking and SU(3) symmetry breaking for the singlet ( $g_A^0$ ) and non-singlet ( $g_A^3$  and  $g_A^8$ ) axial-vector coupling constants. In addition to studying the total strange singlet and non-singlet contents ( $G_s^0(Q^2)$ ,  $G_s^3(Q^2)$  and  $G_s^8(Q^2)$ ) of the nucleon determining the strange quark contribution to the nucleon spin ( $\Delta s$ ), we have also used the conventional dipole

form of parametrization to analyse the  $Q^2$  dependence of the axial-vector form factors  $G_A^0(Q^2)$ ,  $G_A^3(Q^2)$  and  $G_A^8(Q^2)$ .

**WG1+WG5 Joint Session / 45**

## Impact of heavy-flavour production cross sections measured by the LHCb experiment on parton distribution functions at low $x$ .

**Author:** Katerina Lipka<sup>1</sup>

**Co-author:** Collaboration PROSA<sup>2</sup>

<sup>1</sup> DESY

<sup>2</sup> .

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The impact of recent measurements of heavy-flavour production in deep inelastic electron-proton scattering and in proton-proton collisions on parton distribution functions is studied in a QCD analysis in the fixed-flavour number scheme at next-to-leading order.

Differential cross sections of charm- and beauty-hadron production measured by LHCb are used together with inclusive and heavy-flavour production cross sections in deep inelastic scattering at HERA. The heavy-flavour data of the LHCb experiment impose additional constraints on the gluon and the sea-quark distributions at low partonic fractions  $x$  of the proton momentum, down to  $x \sim 5 \times 10^{-6}$ . This kinematic range is currently not covered by other experimental data in perturbative QCD fits.

**WG3+WG4 Joint session / 46**

## Pseudo-observables in Higgs decays

**Authors:** Admir Greljo<sup>1</sup>; David Marzocca<sup>2</sup>; Gino Isidori<sup>3</sup>; Martin Gonzalez-Alonso<sup>4</sup>

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We introduce a set of pseudo-observables, defined from the on-shell amplitudes, characterizing the properties of Higgs decays in generic extensions of the Standard Model with no new particles below the Higgs mass. These provide a systematic generalization of the kappa framework used by the LHC experiments. The pseudo-observables allow for a systematic inclusion of higher order QED and QCD corrections, and can be computed in any EFT approach to Higgs physics. Symmetries of the new-physics sector, such as CP invariance, lepton-universality, and custodial symmetry, imply relations among the pseudo-observables, which could be tested directly from Higgs data.

**WG4+WG5 Joint Session / 47**

## Combination of $D^*$ Differential Cross-Section Measurements in Deep-Inelastic ep Scattering at HERA

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H1 and ZEUS have published single-differential cross sections for inclusive  $D$  meson production in deep-inelastic ep scattering at HERA from their respective final data sets. These cross sections are combined in the common visible phase space region of photon virtuality  $Q^2 > 5 \text{ GeV}^2$ , electron inelasticity  $0.02 < y < 0.7$  and the  $D$  meson's transverse momentum  $p_T(D) > 1.5 \text{ GeV}$  and pseudorapidity  $|\eta(D)| < 1.5$ . The combination procedure takes into account all relevant correlations yielding significantly reduced experimental uncertainties. To extend the kinematic range down to  $Q^2 > 1.5 \text{ GeV}^2$ , double-differential cross sections are also combined with a subset of earlier  $D^*$  data. Perturbative next-to-leading order QCD predictions are compared to the results.

**WG1 Structure Functions and Parton Densities / 48**

## Combined Measurement of Inclusive ep Scattering Cross Sections at HERA

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A combination is presented of all inclusive deep inelastic cross sections measured by the H1 and ZEUS collaborations in neutral and charged current unpolarised ep scattering at HERA. The data correspond to a luminosity of about  $1 \text{ fb}^{-1}$  and span six orders of magnitude in negative four-momentum-transfer squared,  $Q^2$ , and Bjorken  $x$ . They include data taken at proton beam energies of 920, 820, 575 and 460 GeV. The combination method took the correlations of the systematic uncertainties into account, resulting in improved accuracy.

**WG1 Structure Functions and Parton Densities / 49**

## QCD Analysis HERAPDF2.0 of the combined HERA structure function data

**Authors:** Collaborations H1 and ZEUS<sup>1</sup>; Matthew Wing<sup>2</sup>; Stefan Schmitt<sup>3</sup>

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The new combined inclusive HERA cross sections were input to QCD analyses at NNLO, NLO and LO providing a new set of parton distribution functions, HERAPDF2.0. Besides the small experimental uncertainties, model and parameterisation uncertainties were also considered. The consistency of data and the QCD fit was tested for variants of the fit such as the treatment of heavy flavour production and the threshold in  $Q^2$  for including data points in the fit.

**WG1+WG5 Joint Session / 50**



## QCD Analysis of the combined HERA inclusive data together with HERA jet and charm data

**Authors:** Collaboration H1 and ZEUS<sup>1</sup>; Matthew Wing<sup>2</sup>; Stefan Schmitt<sup>3</sup>

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An extended QCD analysis of the new combined inclusive HERA was performed at NLO, also including HERA data on jet and charm production. This enables the simultaneous measurement of parton distribution functions and the strong coupling using data from HERA alone. The strong coupling is measured to be  $\alpha_s(M_Z) = 0.1182 \pm 0.0008(\text{exp}) \pm 0.0005(\text{model/param.}) \pm 0.0012(\text{hadronisation}) \pm 0.0037\text{-}0.0030$  (scale).

### WG6 Spin Physics / 51

## The DVCS physics program at COMPASS

**Author:** Philipp Karl Jorg<sup>1</sup>

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A major part of the COMPASS-II program will be dedicated to the investigation of generalized parton distributions (GPDs) and transverse momentum dependent parton distributions (TMDs), which aim for the most complete description of the partonic structure of the nucleon.

GPDs are experimentally accessible via lepton-induced exclusive reactions, in particular the Deeply Virtual Compton Scattering (DVCS) and Deeply Virtual Meson Production (DVMP). At COMPASS, those processes are investigated using an high intensity muon beam of 160 GeV and a 2.5 m-long liquid hydrogen target. In order to optimize the selection of exclusive reactions at those energies, the target is surrounded by a new barrel-shaped time-of-flight system to detect the recoiling particles.

COMPASS-II covers the up to now unexplored  $x_{Bj}$  domain ranging from 0.01 to 0.15. The option to change simultaneously the charge and polarization of the muon beam allows to access the Compton form factor related to the dominant GPD  $H$ , and thus to provide new experimental constraints

on the theoretical GPD models in the intermediate  $x_{Bj}$  regime.

Moreover, the  $x_{Bj}$ -dependence of the nucleon transverse size is investigated via the pure DVCS cross-section that can be extracted from the sum of cross-sections measured with positive and negative beam polarity.

Preliminary results of pilot measurements and projections on the achievable accuracies will be presented.

Supported by BMBF and EU FP7 (Grant Agreement 283286)

On Behalf of the COMPASS Collaboration

## WG4 QCD and Hadronic Final States / 53

**Scattering amplitudes in TMD-factorisation via BCFW recursion****Author:** Mirko Serino<sup>1</sup><sup>1</sup> *Institute of Nuclear Physics, PAN, Cracow*

We use an extension of the Britto-Cachazo-Feng-Witten (BCFW) recursion relation to evaluate analytically tree-level 5-point matrix elements of two fermions and three gluons with one of the partons off the mass-shell, while preserving gauge invariance.

These amplitudes find their domain of application within the high-energy factorisation (or TMD-factorisation) framework, which requires partons in the scattering process to have an off-shell momentum.

## WG5 Heavy Flavours / 55

**N<sup>3</sup>LO approximate results for top-quark differential cross sections and forward-backward asymmetry****Author:** Nikolaos Kidonakis<sup>1</sup><sup>1</sup> *Kennesaw State University***Corresponding Author:** nkidonak@kennesaw.edu

I present a calculation of approximate N<sup>3</sup>LO corrections from NNLL soft-gluon resummation for differential distributions in top-antitop pair production in hadronic collisions. I show that soft-gluon corrections are the dominant contribution to top-quark production and closely approximate exact results through NNLO. I show aN<sup>3</sup>LO results for the total  $t\bar{t}$  cross section, the top-quark  $p_T$  and rapidity distributions, and the top-quark forward-backward asymmetry. The higher-order corrections are significant and they reduce theoretical uncertainties.

## WG3:Electroweak Physics and Beyond the Standard Model / 56

**The Q-Weak Experiment: Measurement of the Weak Charge of the Proton****Author:** Dave Gaskell<sup>1</sup><sup>1</sup> *Jefferson Lab***Corresponding Author:** gaskelld@jlab.org

The weak charge of the proton,  $Q_W^p$ , has been measured precisely for the first time at Jefferson Lab. The running of the weak mixing angle ( $\sin^2 \theta_W/2$ ), and thus  $Q_W^p$ , from the  $Z$ -pole to the low momentum transfers of this measurement is potentially sensitive through radiative corrections to new physics beyond the Standard Model.

The Q-Weak experiment ran in Hall C from 2010-2012 and measured the parity-violating asymmetry in elastic electron-proton scattering at  $Q^2=0.025$  (GeV/c)<sup>2</sup>. This talk will present the initial results from this experiment from about 4% of the total data sample collected.  $Q_W^p$  was

extracted using this data point in combination with higher  $Q^2$  parity-violating electron-scattering data and state-of-the-art theoretical calculations, used to constrain hadronic effects. The analysis status of the full data set, as well as several ancillary measurements will also be discussed.

WG6 Spin Physics / 57

## Transverse single-spin asymmetries in pion and photon production from proton-proton collisions

**Author:** Daniel Pitonyak<sup>1</sup>

**Co-authors:** Andreas Metz<sup>2</sup>; Koichi Kanazawa<sup>2</sup>; Yuji Koike<sup>3</sup>

<sup>1</sup> Brookhaven National Lab

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Transverse single-spin asymmetries (TSSAs), denoted  $A_N$ , in single-inclusive hard scattering processes are fundamental observables to test perturbative QCD that have been around for almost 40 years. However, many open issues remain as to the origin of TSSAs. Currently two theoretical formalisms are widely used: collinear twist-3 (CT3) factorization and the Generalized Parton Model (GPM). We discuss our work in this area using the framework of the former, including recent calculations of pion and direct photon production in proton-proton collisions. We show how the TSSA for  $pp \rightarrow \pi X$  could mainly come from fragmentation, which could allow for a resolution of the “sign-mismatch” between the Qiu-Sterman (QS) function and the Siverson function. This study also shows a simultaneous description of spin/azimuthal asymmetries in  $pp$ , SIDIS, and  $e+e-$  is possible. For  $A_N$  in  $pp \rightarrow \gamma X$ , we demonstrate how this reaction can allow for a “clean” extraction of the QS function, test the process dependence of the Siverson function, and distinguish between the CT3 and GPM approaches. Given the progress that has been made so far, continued experimental and theoretical work could finally allow us to understand this longstanding problem.

WG6 Spin Physics / 58

## Update on the phenomenology of collinear Dihadron FFs.

**Author:** Aurore Courtoy<sup>1</sup>

**Co-authors:** Alessandro Bacchetta<sup>2</sup>; Marco Radici<sup>3</sup>

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We present an updated extraction of the valence transversity PDF using the most recent COMPASS data with identified pion pairs. The new analysis was carried out using the replica method for both the chiral-odd DiFF and the transversity PDF. This picture represents the current most realistic estimate of the uncertainties on our knowledge of the valence components of the transversity function and the resulting tensor charge. We comment on the implication of the tensor charge’s accuracy on possible new physics.

## WG3:Electroweak Physics and Beyond the Standard Model / 59

**Particle Dark Matter at Hadron Colliders****Author:** Matthew Low<sup>1</sup><sup>1</sup> *University of Chicago***Corresponding Author:** mattlow@ias.edu

In weak-scale theories of beyond the Standard Model physics, particle dark matter is ubiquitous. This is for good reason as observations point towards TeV-scale dark matter with weak-strength interactions. One promising way to search of this type of dark matter is via production at hadron colliders. In this talk I will discuss strategies for searching for dark matter at colliders and present projections on the sensitivity of colliders to simplified models and to neutralino dark matter.

## WG3:Electroweak Physics and Beyond the Standard Model / 60

**Parity Violation Deep Inelastic Scattering Experiments at JLab****Author:** Vincent Sulkosky<sup>1</sup><sup>1</sup> *MIT*

We report on a measurement of parity-violating (PV) asymmetries in the deep inelastic scattering (DIS) and nucleon resonance regions using inclusive scattering of longitudinally polarized electrons from unpolarized deuterons. The effective weak couplings  $C_{2q}$  are accessible through these PV-DIS asymmetries. This measurement of the PV asymmetry yielded a determination of  $2C_{2u} - C_{2d}$  with an improved precision of a factor of five relative to previous results. These results indicate evidence with 95% confidence that the  $2C_{2u} - C_{2d}$  is non-zero. This experiment also provides the first parity-violation data covering the whole resonance region, which provide constraints on nucleon resonance models. The program to measure PV-DIS at JLab in the 12 GeV era will also be briefly discussed.

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**Search for QCD Instanton-Induced Processes in Deep-Inelastic Scattering at HERA****Author:** Collaboration H1<sup>1</sup>**Co-authors:** Karin Daum<sup>2</sup>; Stefan Schmitt<sup>3</sup><sup>1</sup> *DESY*<sup>2</sup> *University of Wuppertal/DESY*<sup>3</sup> *Deutsches Elektronen-Synchrotron (DE)***Corresponding Author:** daum@mail.desy.de

Signals of QCD instanton-induced processes are searched for in deep-inelastic scattering at the electron-proton collider HERA in the kinematic region defined by the Bjorken-scaling variable  $x >$

10–3, the inelasticity  $0.2 < y < 0.7$  and the photon virtuality  $150 < Q^2 < 15000 \text{ GeV}^2$ . The search is performed using H1 data corresponding to an integrated luminosity of  $351 \text{ pb}^{-1}$ . No evidence for the production of QCD instanton-induced events is observed and upper limit is set on the instanton cross-section at 95% confidence level.

## WG1 Structure Functions and Parton Densities / 62

### Quark-hadron duality in the free neutron F2 structure function

**Author:** Gabriel Niculescu<sup>1</sup>

<sup>1</sup> *James Madison University*

The Jefferson Lab. experiment BONuS used a novel spectator-tagging technique to measure the inclusive electron-free neutron scattering cross section and extract the F2 structure function. This data was used to reconstruct moments of F2 in the three prominent resonance region, as well as the moments integrated over the entire resonance region.

Comparisons of the experimental results with moments obtained from global parton distribution function parametrizations seem to suggest that the quark-hadron duality hypothesis holds locally for the neutron in the second and third resonance regions down to  $Q^2$  of  $1 \text{ GeV}^2$ , with up to 20% violations observed in the first resonance region.

## WG6 Spin Physics / 63

### Recent results from PHENIX on double helicity asymmetry ( $A_{LL}$ ) measurement at center of mass energy of $\sqrt{s} = 510 \text{ GeV}$

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One of the major objectives of the RHIC spin program at BNL is the measurement of the gluon helicity contribution,  $\Delta G$ , to the proton spin via measuring the double longitudinal spin asymmetry ( $A_{LL}$ ) in various channels. In PHENIX (Pioneering High Energy Nuclear Interaction eXperiment) the  $A_{LL}$  in  $\pi^0$ ,  $\eta$ ,  $J/\psi$  etc. are measured in wide rapidity range. In this talk,  $A_{LL}$  in  $\pi^0$  production in central rapidity and  $J/\psi$  production in forward rapidity will be discussed. The  $\pi^0$  is reconstructed through its diphoton decay channel within the rapidity range of  $|\eta| < 0.35$  and azimuthal angle of  $180^\circ$ . Similarly,  $J/\psi$  is reconstructed via dimuon decay channel within the rapidity range of  $1.2 < |\eta| < 2.2$ . Preliminary results for  $A_{LL}$  in  $\pi^0$  and  $J/\psi$  production from the data collected in the year 2013 at center of mass energy ( $\sqrt{s}$ ) = 510 GeV will be presented. Also, their impact on  $\Delta G$  constraint will be discussed. In year 2013, the total integrated luminosity was  $150 \text{ pb}^{-1}$  which is almost ten times the total luminosity recorded in the year 2009 at  $\sqrt{s} = 200 \text{ GeV}$ . Due to increase in the center of mass energy and integrated luminosity, the new measurements can cover the Bjorken x range down to 0.01 for  $\pi^0$  and 0.002 for  $J/\psi$ .

**WG1 Structure Functions and Parton Densities / 64****New CTEQ-Jefferson Lab (CJ) analysis of parton distributions**

**Authors:** Alberto Accardi<sup>1</sup>; Eric Christy<sup>2</sup>; Jeff Owens<sup>3</sup>; Lucas Brady<sup>4</sup>; Nobuo Sato<sup>5</sup>; Peter Ehlers<sup>6</sup>; Peter Monaghan<sup>7</sup>; Thia Keppel<sup>5</sup>; Wally Melnitchouk<sup>5</sup>

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We present preliminary results of a new global QCD analysis of PDFs from the CTEQ-Jefferson Lab Collaboration (dubbed “CJ15”), which includes several new data sets and recent theoretical developments. In particular, we study the constraints from new D0 data on  $W$  boson asymmetries on the  $d/u$  PDF ratio at large  $x$ , and, indirectly, on the models of nuclear corrections in the deuteron. The analysis also considers for the first time the impact of Jefferson Lab data on the free neutron/deuteron structure function ratio at large  $x$ , and reanalyzes the light antiquark asymmetry in the proton from Drell-Yan data using more flexible parametrizations and nuclear corrections to deuterium cross sections. The results provide a new set of baseline PDFs which can be used to more reliably calibrate the effect of future data from the LHC.

**WG1 Structure Functions and Parton Densities / 68****HERAFitter project and its related studies**

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The uncertainties of protons parton distribution functions (PDFs) play a dominant role for the precision tests of the Standard Model (SM) and they also impact substantially the theory predictions of Beyond SM high mass production. We present the HERAFitter project which provides a unique open-source software framework for the determination of the proton’s PDFs and for the interpretation of the physics analyses in the context of Quantum Chromodynamics (QCD).

We report here the highlighted results based on the HERAFitter functionalities, as well as novel studies performed by HERAFitter. The latter includes the impact of correlations between uncertainties for PDFs extracted at different perturbative QCD orders as well as the QCD analysis of the recent Drell-Yan production measurements at Tevatron.

**WG4 QCD and Hadronic Final States / 69**

## Fast evaluation of theoretical uncertainties with Sherpa and MC-grid

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The determination of theoretical error estimates and PDF/ $\alpha_s$ -fits require fast evaluations of differential cross sections for varied QCD input parameters.

These include PDFs, the strong coupling constant  $\alpha_S$  and the renormalization and factorization scales.

Beyond leading order QCD, a full dedicated calculation for each set of parameters is often too time-consuming, certainly when performing PDF-fits.

In this talk we discuss two methods to overcome this issue for any QCD NLO calculation:

The novel event-reweighting feature in Sherpa and the automated generation of interpolation grids using the recently introduced MCgrid interface.

For MCgrid we present the newly added support for fastNLO tables and highlight some future developments.

WG6 Spin Physics / 70

## JAM global QCD analysis of spin-dependent parton distributions

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A new global QCD analysis of spin-dependent PDFs has been performed by the JAM (Jefferson Lab Angular Momentum) Collaboration, including all available data on inclusive spin structure functions from CERN, SLAC, DESY and JLab. In particular, we explore the impact of recent high-precision JLab data at high  $x$  and low  $Q^2$  on the determination of large- $x$  PDFs and the extraction of higher twist matrix elements.

Preliminary results for a global fit including also jet and pion production data from  $pp$  scattering at RHIC are also presented.

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## New limits on intrinsic charm in the nucleon from global analysis

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We present a new global QCD analysis of parton distribution functions, allowing for possible intrinsic charm (IC) contributions in the nucleon inspired by light-front models. The analysis makes use of the full range of available high-energy scattering data for  $Q^2 > 1 \text{ GeV}^2$  and  $W^2 > 3.5 \text{ GeV}^2$ , including fixed-target proton and deuteron cross sections at lower energies that were excluded in previous global analyses. The expanded data set places more stringent constraints on the momentum carried by IC, with  $\langle x \rangle_{\text{IC}}$  at most 0.5% (corresponding to an IC normalization of  $\sim 1\%$ ) at the  $4\sigma$  level for  $\Delta\chi^2 = 1$ . We also critically assess the impact of older EMC measurements of  $F_2^c$  at large  $x$ , which favor a nonzero IC, but with very large  $\chi^2$  values.

**WG4 QCD and Hadronic Final States / 72**

## Comparisons of Exact Amplitude-Based Resummation Predictions and LHC Data

**Author:** Aditi Mukhopadhyay<sup>1</sup>

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We present the current status of the comparisons with the respective data of the predictions of our approach of exact amplitude-based resummation in quantum field theory as applied to precision QCD calculations as needed for LHC physics. The agreement between the theoretical predictions and the data exhibited continues to be encouraging.

**WG1 Structure Functions and Parton Densities / 73**

## MMHT 2014 PDFs

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We present the MMHT2014 PDFs, an update of the previous major release in the same framework, i.e. MSTW2008. We discuss the changes in both the central values and uncertainties in the PDFs due to changes in theoretical procedures and the impact of new, largely LHC data-sets. We note, however, that changes in predictions are rather small. We discuss the correlation between the PDFs and the strong coupling constant and the constraint on the latter. We also highlight plans for the future.

**WG2 Small-x, Diffraction and Vector Mesons / 74**



## Higher Fock states in CGC

**Author:** Andrey Grabovskiy<sup>1</sup>

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The next to leading order low  $x$  evolution equation for the next after the dipole operator will be discussed.

WG6 Spin Physics / 75

## Jet measurements in polarized p+p collisions at STAR at RHIC

**Author:** Xuan Li<sup>1</sup>

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Inclusive jet- and di-jet productions in polarized p+p collisions at  $\sqrt{s} = 200$  GeV and  $\sqrt{s} = 500$  GeV provide powerful probes to study gluons inside the proton. Inclusive jet production is sensitive to the integral of the gluon distribution over a broad range of  $x$ . Di-jet production provides better sensitivity to  $x$  dependence of gluons. The Solenoidal Tracker at RHIC (STAR) has the capability, with nearly full azimuthal ( $2\pi$ ) coverage, to reconstruct jets at mid-rapidity ( $|\eta| < 1$ ). Different  $x$  regions of gluons inside the proton can be accessed by the STAR experiment through sampling different center of mass energies and pseudorapidities. Inclusive jet and di-jet cross section measurements at STAR have been found to be in good agreement with NLO pQCD calculations taking into account effects of hadronization and underlying events. The latest STAR inclusive jet double-spin asymmetry  $A_{LL}$  measured in 200 GeV p+p collisions provides the first evidence of non-zero gluon contribution to the proton spin. Selected measurements of inclusive jet and di-jet cross-sections and longitudinal double-spin asymmetries will be presented; including the new inclusive jet cross section using the anti- $k_T$  algorithm with potential insights into PDFs, and the new inclusive jet  $A_{LL}$  measurements in 510 GeV p+p collisions which shows consistent  $x_T$  scaling with the 200 GeV result. In addition, projections for the inclusive jet and di-jet double-spin asymmetries in longitudinal polarized p+p collisions from the latest and future RHIC runs will be discussed.

WG6 Spin Physics / 76

## First L/T separation of $\pi^0$ electroproduction from Jefferson Laboratory Hall A

**Author:** Maxime DEFURNE<sup>1</sup>

<sup>1</sup> *CEA*

The deeply virtual  $\pi^0$  production cross section can be decomposed according to the polarization of the virtual photon.

$\begin{equation}$

$$\frac{d\sigma}{dt} = \frac{d\sigma_T}{dt} + \epsilon \frac{d\sigma_L}{dt} + \sqrt{2\epsilon} \frac{d\sigma_{TL}}{dt} \cos(\phi) + \epsilon \frac{d\sigma_{TT}}{dt} \cos(2\phi)$$

$\end{equation}$

where  $\epsilon$  represents the degree of polarization of the virtual photon and  $\phi$  the angle between the leptonic and the hadronic plane.

The unseparated  $\pi^0$  electroproduction cross sections have been extracted in the Halls A and B of Jefferson Laboratory. Using the  $\phi$ -dependence, both experiments measured a large  $\sigma = \sigma_T + \epsilon\sigma_L$ . However generalized parton distributions-based models predict a small contribution  $\sigma_L$  in a theoretical framework where factorization has only been proven for longitudinal polarized photons.

Assuming the validity of factorization for transverse photons, Kroll and Goloskokov developed a model where the transversity GPDs would couple to the twist-3 distribution amplitudes of the pion, amplifying the  $\sigma_T$  signal. In order to verify this prediction, the E07-007 experiment measured the  $\pi^0$  electroproduction cross section on proton in the Hall A of Jefferson Laboratory. Using two beam energies to measure the cross section at same  $Q^2$  and  $x_B$ , we change the  $\epsilon$  value and are able to separate the transverse from the longitudinal contribution. For the first time, I will present the fully separated  $\pi^0$  electroproduction cross section and compare it to the existing models.

**WG3+WG5 Joint Session / 77**

## Theoretical results for electroweak boson and single-top production

**Author:** Nikolaos Kidonakis<sup>1</sup>

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I present results from recent high-order calculations for the production of electroweak bosons and top quarks. In particular, I discuss W and Z boson production at large transverse momentum, charged Higgs production, FCNC top production, and single-top production. Theoretical predictions which include higher-order soft-gluon corrections are presented for total cross sections and differential distributions at the LHC.

**WG2 Small-x, Diffraction and Vector Mesons / 78**

## Diffraction production of isolated photons at HERA

**Author:** Matthew Wing<sup>1</sup>

<sup>1</sup> *UCL*

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Using data from HERA, the ZEUS collaboration present measurements of the diffractive production of isolated ("prompt") photons in photoproduction, with and without a jet. First cross sections are evaluated for centrally produced photons with jets as a function of the photon and jet transverse energy and pseudorapidity, and also for the fraction of incoming photon energy imparted to the photon-jet system. Comparison is made to predictions from RAPGAP.

**WG5 Heavy Flavours / 79**

## Measurement of $D^*$ photoproduction at three different centre-of-mass energies at HERA

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The photoproduction of  $D^{*\pm}$  mesons has been measured with the ZEUS detector at HERA at three different  $ep$  centre-of-mass energies,  $\sqrt{s}$ , of 318, 251 and 225 GeV. For each data set,  $D^{*\pm}$  mesons were required to have transverse momentum,  $p_T^{D^*}$ , and pseudorapidity,  $\eta^{D^*}$ , in the ranges  $1.9 < p_T^{D^*} < 20$  GeV and  $|\eta^{D^*}| < 1.6$ . The events were required to have a virtuality of the incoming photon,  $Q^2$ , of less than 1 GeV<sup>2</sup>. The dependence on  $\sqrt{s}$  was studied by normalising to the high-statistics measurement at  $\sqrt{s} = 318$  GeV. This led to the cancellation of a number of systematic effects both in data and theory. Predictions from next-to-leading-order QCD describe the  $\sqrt{s}$  dependence of the data well.

**WG2 Small-x, Diffraction and Vector Mesons / 80**

## Measurement of the cross-section ratio $\sigma_{\psi(2S)}/\sigma_{J/\psi}$ in deep inelastic exclusive ep scattering at HERA

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The exclusive deep inelastic electroproduction of  $\psi(2S)$  and  $J/\psi$  has been studied with the ZEUS detector at HERA in the kinematic range  $2 \leq Q^2 \leq 80$  GeV<sup>2</sup>,  $30 \leq W \leq 210$  GeV and  $|t| \leq 1$  GeV<sup>2</sup>, where  $Q^2$  is the photon virtuality,  $W$  is the photon-proton centre-of-mass energy and  $t$  is the squared four-momentum transfer at the proton vertex. The data for  $2 \leq Q^2 \leq 5$  GeV<sup>2</sup> were taken in the HERA I running period and correspond to an integrated luminosity of 114 pb<sup>-1</sup>. The data for  $5 \leq Q^2 \leq 80$  GeV<sup>2</sup> are from both HERA I and HERA II periods and correspond to an integrated luminosity of 468 pb<sup>-1</sup>. The decay modes analysed were  $\mu^+\mu^-$  and  $J/\psi\pi^+\pi^-$  for the  $\psi(2S)$  and  $\mu^+\mu^-$  for the  $J/\psi$  and the cross-section ratio  $\sigma(\psi(2S))/\sigma(J/\psi)$  has been measured as a function of  $Q^2$ ,  $W$  and  $t$ . The measurement is compared to predictions of QCD-inspired models of vector-meson production.

**WG2 Small-x, Diffraction and Vector Mesons / 81**

## Production of exclusive dijets in diffractive deep inelastic scattering at HERA

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The exclusive dijet production in diffractive deep inelastic  $e^+p$  scattering has been measured with the ZEUS detector at HERA using an integrated luminosity of 372 pb<sup>-1</sup>. The measurement was performed for  $\gamma^* - p$  centre-of-mass energies in the range  $90 < W < 250$  GeV and photon virtualities in the range  $Q^2 > 25$  GeV<sup>2</sup>. Energy and transverse-energy flows around the jet axis are presented. The cross section is presented as a function of  $\beta$ , the Bjorken variable defined with respect to the diffractive exchange and, in bins of  $\beta$ , as a function of  $\phi$ , the angle between the  $\gamma^*$ -dijet plane

and the  $\gamma^* - e^\pm$  plane in the rest frame of the dijet final state. The results are compared to predictions from models which are based on different assumptions about the nature of the diffractive exchange.

**WG5 Heavy Flavours / 82**

## Asymmetries in heavy quark production at CDF

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One of the most intriguing measurements in particle physics in recent years is the forward-backward asymmetry of top quark production. Although calculations at next-to-next-to-leading order have largely resolved the anomaly, these measurements are still very interesting as precision tests of the standard model and of physics beyond the standard model. We summarize the results on the top quark forward-backward asymmetry at CDF and present new results from CDF on the bottom quark forward-backward asymmetry.

**WG2 Small-x, Diffraction and Vector Mesons / 83**

## NLO JIMWLK

**Author:** Michael Lublinsky<sup>None</sup>

We present a construction of an effective high energy QCD Hamiltonian at NLO accuracy. This Hamiltonian is an NLO extension of the JIMWLK LO Hamiltonian, known to incorporate BFKL dynamics with gluon saturation phenomena. We are to demonstrate how the conformal symmetry is realized within the NLO JIMWLK.

**WG6 Spin Physics / 84**

## Studies of Collins asymmetries with the BaBar detector

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Inclusive hadron production cross sections and angular distributions in  $e^+e^-$  collisions shed light on fundamental questions of hadronization and fragmentation processes. We present measurements of the so-called Collins azimuthal asymmetries in inclusive production of hadron pairs, in the  $e^+e^- \rightarrow h_1 h_2 X$  annihilation process, where the two hadrons (either kaon or pions) are produced in opposite hemispheres. The data collected by the BaBar detector allows the determination of the Collins fragmentation function as a function of hadron fractional energies and transverse momenta, and can be combined with semi-inclusive deep-inelastic-scattering data to extract the transversity distribution function, which is the least known leading-twist component of the QCD description of the partonic structure of the nucleon.

WG3+WG5 Joint Session / 85

## Recent BaBar results on CP violation in B-meson decays

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We present a selection of recent results on CP violation effects measured with a sample of about 471 million B-Bbar pairs collected by the BaBar detector.

They include a measurement of CP and T asymmetries in the B<sub>0</sub>-B<sub>0</sub>bar mixing process by using inclusive dilepton samples, and a Dalitz plot analysis of the charmless decay B<sup>+</sup> → K<sub>s</sub> π<sup>+</sup> π<sub>0</sub>, where the first evidence of direct CP violation in the B<sup>+</sup> → K<sup>\*</sup> π<sub>0</sub> decay has been seen.

We also present a measurement of the parameter sin<sup>2</sup>β of the Unitarity Triangle in B<sub>0</sub> → D<sub>0</sub> h<sub>0</sub> decays, which makes use of the combined data sets of the BaBar and Belle experiments.

WG3:Electroweak Physics and Beyond the Standard Model / 86

## Direct searches for low-mass new physics particles at BABAR

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We report on the latest searches for low mass states predicted in several

New Physics models performed with the data collected by the BABAR detector.

These include: searches for the so-called dark photons in e<sup>+</sup>e<sup>-</sup> annihilations (e<sup>+</sup>e<sup>-</sup> → γ A', A' → e<sup>+</sup>e<sup>-</sup>, μ<sup>+</sup>μ<sup>-</sup>), and for long-lived particles motivated by recent astrophysical observations; searches for non-standard π<sub>0</sub>-like particle production in e<sup>+</sup>e<sup>-</sup> → τ<sup>+</sup>τ<sup>-</sup> events; and searches for a low mass CP-odd Higgs boson predicted in non-minimal supersymmetric extensions of the Standard Model.

WG2 Small-x, Diffraction and Vector Mesons / 87

## TMDs at Small-x: What We Have Learnt and What We Expect

**Author:** Feng Yuan<sup>1</sup>

<sup>1</sup> *LBNL*

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In this talk, we will discuss the theory developments on the next-to-leading order calculation for forward hadron production in pA collisions in the small-x factorization framework. In particular, we emphasize the matching between this calculation and the collinear factorization calculation at large transverse momentum. The small-x calculation can be viewed as a power series in  $Q_s^2/k_T^2$ , in which the collinear factorization result corresponds to the leading term. At high transverse momentum, the subleading correction terms are insignificant, whereas at low  $p_T$ , the power corrections become important and the small-x resummation is essential to describe the differential cross section. We show that the familiar collinear factorization calculation can smoothly match the results from

small- $x$  factorization at next-to-leading order in  $\alpha_s$  when we use exact kinematics, as opposed to the approximate kinematics in previous work. With this matching, we can describe the experimental data from RHIC very well at high  $p_T$ .

#### WG4 QCD and Hadronic Final States / 88

### Soft Gluon Resummations in Dijet Azimuthal Angular Correlations at the Collider

**Author:** Feng Yuan<sup>1</sup>

<sup>1</sup> *LBNL*

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In this talk, we will present our recent theoretical calculations of all order soft gluon resummation for dijet azimuthal angular correlations at the hadron colliders. The relevant coefficients for the Sudakov resummation factor, the soft and hard factors, are calculated. The theory predictions agree well with the experimental data from D0 Collaboration at the Tevatron, ATLAS and CMS Collaborations at the LHC.

#### WG2 Small-x, Diffraction and Vector Mesons / 89

### Particle production in hybrid formalism revisited

**Author:** Alex Kovner<sup>1</sup>

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We reconsider the perturbative next-to-leading calculation of the single inclusive hadron production in the framework of the hybrid formalism, applied to hadron production in proton-nucleus collisions. We introduce the explicit requirement that fast fluctuations in the projectile wave function which only exist for a short time are not resolved by the target. This Ioffe time cutoff also strongly affects the next-to-leading order terms. Our final expressions are unambiguous and do not coincide at next-to-leading order with the results available in the literature.

#### WG4 QCD and Hadronic Final States / 90

### Automated higher-order calculations: Status and prospects

**Author:** Giovanni Ossola<sup>1</sup>

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This talk will focus on the automation of higher-order QCD calculations.

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## QCD studies at NA48

**Author:** Cristina Lazzeroni<sup>1</sup>

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We report the first observation of the very rare decay  $K^{*-} \rightarrow \pi^{*+} \pi^0 e^+ e^-$  by the NA48/2 experiment. From a clean sample of almost 2000 reconstructed signal events, we have determined the branching fraction with high precision and measured the  $e^+ e^-$  invariant mass distribution, which allows to differentiate between different decay models.

Besides, the NA48/2 experiment has recently published a detailed study of the  $K_{e4}$  decay mode  $K \rightarrow \pi^0 \pi^0 e \nu$  based on 65000 candidates with a low 1% background contamination. The achieved experimental precision brings evidence for isospin breaking mass effects and final state  $\pi \pi$  scattering. Theoretical calculations will have to face a new precision challenge when using such improved inputs to extract for example low energy constants of Chiral Perturbation Theory.

### WG7 Future experiments / 92

## Prospects for $K^+ \rightarrow \pi^+ \nu \nu$ observation at CERN in NA62

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The rare decays  $K^+ \rightarrow \pi^+ \nu \nu$  are excellent processes to make tests of new physics at the highest scale complementary to LHC thanks to their theoretical cleanliness.

The NA62 experiment at CERN SPS aims to collect of the order of 100 events in two years of data taking, keeping the background at the level of 10%.

Part of the experimental apparatus has been commissioned during a technical run in 2012. The physics prospects and the status of the experiment will be reviewed in light of the pilot run in October-December 2014.

### WG2 Small-x, Diffraction and Vector Mesons / 93

## Resummation of Double Logarithms in the Rapidity Evolution of Color Dipoles

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Starting at NLO, the BFKL-BK evolution in high-energy QCD develops severe convergence problems. The most important source for this behavior can be traced down to large double collinear logarithms. We show via explicit computation of Feynman diagrams that corrections enhanced by double logs correspond to soft gluon emissions strongly ordered in lifetime, while other potential contributions cancel among themselves. We manage to incorporate these corrections in a local-in-rapidity BK evolution equation, with modified kernel and initial conditions. Numerical studies of the improved BK equation demonstrate the essential role of the resummation in both stabilizing and slowing down the evolution.

#### WG1 Structure Functions and Parton Densities / 94

### nCTEQ15 – Global analysis of nuclear parton distributions with uncertainties

**Authors:** Aleksander Kusina<sup>1</sup>; Cynthia Keppel<sup>2</sup>; Fred Olness<sup>3</sup>; Ingo Schienbein<sup>4</sup>; J. Y. Yu<sup>3</sup>; Jorge G. Morfin<sup>5</sup>; Joseph Owens<sup>6</sup>; Karol Kovarik<sup>None</sup>; Tomas Jezo<sup>7</sup>

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We present the first official release of the nCTEQ nuclear parton distribution functions with errors. The main addition to the previous nCTEQ PDFs is the introduction of PDF uncertainties based on the Hessian method. Another important addition is the inclusion of pion production data from RHIC giving us a handle to constrain gluon PDF.

In this presentation we briefly discuss the framework of our analysis and concentrate on the comparison of our results with those of other groups providing nuclear parton distributions.

#### WG1 Structure Functions and Parton Densities / 95

### Neutrino scattering physics with the SHIP Experiment

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SHIP is a new general purpose fixed target facility, proposed at the CERN SPS accelerator. In its initial phase the 400GeV proton beam will be dumped on a heavy target with the aim of integrating  $2 \times 10^{20}$  pot in 5 years.

A dedicated detector downstream the target will allow to probe a variety of models with light long-lived exotic particles and masses below  $O(10)$  GeV/c<sup>2</sup>

Another dedicated detector will allow the study of active neutrino cross-sections and angular distributions, and this will be the focus of the talk.

In particular tau neutrino deep inelastic cross sections will be performed with a statistics 1000 times larger than currently available, with the extraction of the  $F_4$  and  $F_5$  structure functions, never measured so far. Tau neutrinos will be distinguished by tau anti-neutrinos, thus providing the first



observation for the tau anti-neutrino.

With muon neutrinos it will be possible to study the strange content of the nucleon with a statistics 100 times larger than currently available

Eventually with electron neutrinos it will be possible to improve the deep inelastic cross section measurement, in particular at high energy, where present measurements have large uncertainties.

## WG7 Future experiments / 96

### THE SHIP experiment and its detector for neutrino physics

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Another dedicated detector, that will be the focus of this talk, will allow to study active neutrino cross-sections and angular distributions

The neutrino detector consists of an emulsion target, based on the Emulsion Cloud Chamber technology fruitfully employed in the OPERA experiment. The Emulsion Cloud Chamber will be placed in a magnetic field, with the so-called Compact Emulsion spectrometer, a few cm thick chamber for the charge and momentum measurement of hadrons. This will provide the leptonic number measurement also in the hadronic tau decay channels. The detector will be hybrid, using nuclear emulsions and electronic detectors for the time stamp of the events and the measurement of the muon momentum. The muon system will also be based on the design of the one used in the OPERA experiment.

## WG2 Small-x, Diffraction and Vector Mesons / 97

### Saturation and geometrical scaling: from small x DIS to high energy heavy ion collisions

**Author:** Michal Praszalowicz<sup>1</sup>

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Gluon distributions of colliding hadrons saturate as a consequence of non-linear evolution equations of QCD. Saturation implies the existence of the so called saturation momentum, which is related to the gluon density per unit rapidity per transverse area. At large energies in some regions of phase space the saturation momentum is the only scale for physical processes. As a consequence different observables exhibit so called geometrical scaling (GS). We shall briefly discuss theoretical aspects of saturation and then show a number of examples of GS and its violation in different reactions.

## WG1 Structure Functions and Parton Densities / 98

**Generalized Parton Distributions: A Dyson-Schwinger approach for the pion.****Author:** Cedric Mezrag<sup>None</sup>**Co-authors:** Craig Roberts<sup>1</sup>; Franck Sabatié<sup>2</sup>; Hervé MOUTARDE<sup>3</sup>; José Rodriguez Quintero<sup>4</sup><sup>1</sup> Argonne National Laboratory<sup>2</sup> CEA Saclay<sup>3</sup> Irfu, CEA-Saclay<sup>4</sup> University of Huelva**Corresponding Author:** cedric.mezrag@cea.fr

We compute the pion quark Generalized Parton Distribution  $H$  and quark Double Distributions in a coupled Bethe-Salpeter and Dyson-Schwinger approach in terms of quarks flavors or isospin states. We use simple analytic expressions inspired by the numerical resolution of Dyson-Schwinger and Bethe-Salpeter equations. We obtain an analytic expression for the pion Generalized Parton Distribution at a low scale. Our model fulfils most of the required symmetry properties and compares very well to experimental pion form factor or parton distribution function (PDF) experimental data. In addition, we have highlighted gluons contributions which play a significant role when computing the PDF and which were neglected before.

## WG1 Structure Functions and Parton Densities / 100

**Nuclear PDF constraints from p+Pb collisions at the LHC****Author:** Ilkka Helenius<sup>1</sup>**Co-authors:** Hannu Paukkunen<sup>2</sup>; Kari J. Eskola<sup>3</sup><sup>1</sup> Lund University<sup>2</sup> University of Jyväskylä<sup>3</sup> University of Jyväskylä**Corresponding Author:** ilkka.helenius@thep.lu.se

The current nuclear PDF analyses are mainly constrained by fixed-target DY and DIS data which provide direct constraints primarily for quarks at  $x > 0.001$ . Some constraints for gluons are provided by the inclusive pion production data in d+Au collisions at RHIC but due to the limited kinematic reach of the data the small- $x$  nuclear gluon PDFs remain practically unconstrained in the current fits. In this talk I will discuss how the existing data from p+Pb collisions at the LHC can improve the nPDF fits and which measurements would further improve the kinematical coverage. In particular, I will quantify the  $x$  regions probed by inclusive hadron production at different rapidities and compare this to corresponding distributions for prompt photon production. Our results indicate that the prompt photons are more sensitive to the small- $x$  region than the inclusive hadrons and that the sensitivity can be further increased by imposing an isolation cut for the prompt photons. Also EPS09-based NLO predictions for the isolated photon nuclear modification ratio and forward-to-backward asymmetry are presented.

## WG7 Future experiments / 101

**VHEeP: A very high energy electron-proton collider based on proton-driven plasma wakefield acceleration****Authors:** Allen Caldwell<sup>1</sup>; Matthew Wing<sup>2</sup><sup>1</sup> *Max Planck Institute*<sup>2</sup> *UCL***Corresponding Author:** mw@hep.ucl.ac.uk

Based on current CERN infrastructure, an electron-proton collider is proposed at a centre-of-mass energy of about 9 TeV. A 7 TeV LHC bunch is used as the proton driver to create a plasma wakefield which then accelerates electrons to 3 TeV, these then colliding with the other 7 TeV LHC proton beam. The basic parameters of the collider are presented, which although of very high energy, has integrated luminosities of the order of  $10 \text{ pb}^{-1}/\text{year}$ . For such a collider, with a centre-of-mass energy 30 times greater than HERA, parton momentum fractions,  $x$ , down to about  $10^{-8}$  are accessible for  $Q^2$  of  $1 \text{ GeV}^2$  and could lead to effects of saturation or some other breakdown of DGLAP being observed. The total photon-proton cross section can be measured up to very high energies and also at different energies as the possibility of varying the electron beam energy is assumed; this could have synergy with cosmic-ray physics. Other physics which can be pursued at such a collider are contact interaction searches, such as quark and electron substructure, and measurements of the proton structure as well as other more conventional measurements of QCD at high energies and in a new kinematic regime. The events at very low  $x$  will lead to electrons and the hadronic final state produced at very low angles and so a novel spectrometer device will be needed to measure these. First ideas of the physics programme of such a collider are given.

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**Nucleon Tensor Charge from Collins Azimuthal Asymmetry Measurements****Author:** Alexei Prokudin<sup>1</sup>**Co-authors:** Feng Yuan<sup>2</sup>; Zhongbo Kang<sup>3</sup>; peng sun<sup>2</sup><sup>1</sup> *Jefferson Lab*<sup>2</sup> *LBNL*<sup>3</sup> *Los Alamos National Laboratory***Corresponding Author:** prokudin@to.infn.it

We investigate the nucleon tensor charge from current experiments by a combined analysis of the Collins asymmetries in two hadron production in  $e^+e^-$  annihilations and single inclusive hadron production in deep inelastic scattering processes. The transverse momentum dependent evolution is taken into account, for the first time, in the global fit of the Collins fragmentation functions and the quark transversity distributions at the approximate next-to-leading logarithmic order. We obtain the nucleon tensor charge contribution from up and down quarks as:  $\delta u = +0.30_{-0.11}^{+0.12}$  and  $\delta d = -0.20_{-0.13}^{+0.35}$  at 90% of confidence level for momentum fraction  $0.0065 \leq x_B \leq 0.35$  and  $Q^2 = 10 \text{ GeV}^2$ .

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## Extraction of the distribution function $h_{1T}^\perp$ from experimental data

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

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We attempt an extraction of the pretzelosity distribution ( $h_{1T}^\perp$ ) from preliminary COMPASS, HERMES, and JLAB experimental data on  $\sin(3\phi_h - \phi_S)$  asymmetry on proton, and effective deuteron and neutron targets. The resulting distributions, albeit with big errors, for the first time show tendency for up-quark pretzelosity to be positive and down-quark pretzelosity to be negative. A model relation of pretzelosity distribution and orbital angular momentum of quarks is used to estimate contributions of up and down quarks.

**WG6 Spin Physics / 104**

## Left-right asymmetry of transverse densities from chiral dynamics

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The nucleon's peripheral transverse charge and magnetization densities are computed in chiral effective field theory in the light-front formulation. The densities are represented in first-quantized form, as overlap integrals of chiral light-front wave functions describing the transition of the nucleon to soft pion-nucleon intermediate states. The new representation leads to a simple quantum-mechanical picture, according to which the orbital motion of the soft pion causes a left-right asymmetry of the light-front current density in a transversely polarized nucleon. The sizeable effect attests to the essentially relativistic nature of chiral dynamics [momenta  $k_\pi = O(M_\pi)$ ] and could be observed in elastic form factor measurements at low momentum transfer. Further applications of this formulation are presented in connection to peripheral GPDs at low  $x$  and to form factors of the energy momentum tensor which potentially contribute to a model independent understanding of the proton spin problem.

**WG2 Small-x, Diffraction and Vector Mesons / 105**

## Holographic Approach to DIS at Small-x at High Energy

**Author:** Chung-I Tan<sup>1</sup>

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We focus on a holographic approach to DIS at small- $x$  in high energy where scattering is dominated by exchanging a Reggeized Graviton in  $AdS_5$ . We emphasize the importance of confinement, which corresponds to a deformation of  $AdS_5$  geometry in the IR. This approach provides an excellent fit to the combined HERA data at small  $x$ . We also discuss the constraints of unitarity and causality, and show how these constraints are resolved by the inclusion of string modes.

**WG3:Electroweak Physics and Beyond the Standard Model / 106**

## Electroweak Corrections at the LHC

**Authors:** Doreen Wackerroth<sup>1</sup>; Jia Zhou<sup>1</sup>; John Campbell<sup>2</sup><sup>1</sup> *SUNY at Buffalo*<sup>2</sup> *Fermilab***Corresponding Author:** jiazhou@buffalo.edu

Electroweak (EW) corrections at the LHC can be enhanced at high energies due to soft/collinear radiation of W and Z bosons, being dominated by Sudakov-like corrections in the form of  $\alpha_W^l \log^n(Q^2/M_W^2)$  ( $n \leq 2l - 1$ ,  $\alpha_W = \frac{\alpha}{4\pi \sin^2 \theta_W}$ ) when the energy scale  $Q$  enters the TeV regime. Thus, the inclusion of EW corrections in LHC predictions is important for the search of possible new physics in tails of distributions. EW corrections should also be taken into account in virtue of its comparable size ( $\mathcal{O}(\alpha)$ ) to that of higher order QCD corrections ( $\mathcal{O}(\alpha_s^2)$ ).

We calculated the next-to-leading-order (NLO) weak corrections to the neutral-current (NC) Drell-Yan process, top-quark pair production and dijet production, respectively, and implemented them in the Monte-Carlo program MCFM. This enables a combined study with the corresponding NLO QCD corrections. We provide both the full NLO weak corrections and their weak Sudakov approximation valid at high energies. The latter is often used for a fast evaluation of weak effects, and having the exact result available as well allows to quantify the validity of the Sudakov approximation.

**WG2 Small-x, Diffraction and Vector Mesons / 107**

## Recent TOTEM Results and Perspectives for the LHC Run 2

**Author:** Mario Deile<sup>1</sup><sup>1</sup> *CERN***Corresponding Author:** mario.deile@cern.ch

We present the final results on low- $|t|$  elastic proton-proton scattering at  $\sqrt{s} = 8$  TeV based on two data sets acquired with different, dedicated beam-optics settings. A very high statistics sample allowed, for the first time at LHC energies, the exclusion of a purely exponential differential cross-section in the four-momentum range  $0.027 < |t| < 0.2$  GeV<sup>2</sup> with a significance greater than 7 sigma. Two extended parametrisations, with quadratic and cubic polynomials in the exponent, are shown to be well compatible with the data.

Another data sample covered the range  $6 \times 10^4 \text{ GeV}^2 < |t| < 0.2$  GeV<sup>2</sup>, giving access to the

region of interference between the hadronic and the electromagnetic scattering amplitudes, again for the first time at LHC. We present the measured cross-section and its interpretation for different assumptions on the functional forms of the interference term and of the phase of the hadronic elastic amplitude.

The conditional results for the  $\rho$  parameter, i.e. the arctangent of the hadronic phase at  $t = 0$ , are reported.

The second part of the presentation is dedicated to the Roman Pot upgrade realised during the first long shutdown of the LHC and the resulting physics prospects for Run 2. Particular focus will be put on explaining the potential for observing and characterising glueball states produced exclusively by Double Pomeron Exchange and tagged by detecting both surviving protons in the Roman Pots.

## WG6 Spin Physics / 108

### Next-to-leading order weighted Sivvers asymmetry in semi-inclusive deep inelastic scattering: three-gluon correlator

**Author:** LINGYUN DAI<sup>1</sup>

**Co-authors:** Alexei Prokudin<sup>2</sup>; Ivan Vitev<sup>3</sup>; Zhongbo Kang<sup>4</sup>

<sup>1</sup> *Indiana University*

<sup>2</sup> *Jefferson Lab*

<sup>3</sup> *Los Alamos National Laboratory*

<sup>4</sup> *Brookhaven National Laboratory*

We study the Sivvers asymmetry in semi-inclusive hadron production in deep inelastic scattering. In particular, we concentrate on the contribution from the photon-gluon fusion channel, where the three-gluon correlation functions play the major role within a twist-3 collinear factorization formalism. We establish the matching between such a formalism and the usual transverse momentum dependent (TMD) factorization formalism at the moderate hadron transverse momentum, for the three-gluon correlation functions. We derive the so-called coefficient functions used in the usual TMD evolution formalism, where one expands the quark Sivvers function in the  $b$ -space in terms of the collinear twist-3 three-gluon correlation functions. We further perform the next-to-leading order calculation for the transverse-momentum-weighted spin-dependent differential cross section, from which we identify the off-diagonal contribution from the three-gluon correlation functions to the QCD collinear evolution of the twist-3 Qiu-Sterman function.

## WG2 Small-x, Diffraction and Vector Mesons / 109

### Sarte, a generator for diffractive vector meson production in ep and eA collisions

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The demand for detailed simulations of diffractive processes at an electron-ion collider (EIC) required the realization of an event generator that described these processes not only in ep but especially also in eA. Since gluon saturation is one of the key topics in eA collisions at an EIC, the generator was also required to be able to describe these non-linear QCD phenomena but also be able to simulate the linear (non-saturated) case as reference.

The Sartre event generator was written to fulfill these needs. It is based on a new technique to calculate the cross-section based on the bSat dipole model.

In this talk I will describe the physics behind the generator and show results of simulations for an EIC of various observables such as diffractive vector meson production and the ratio of diffractive over total cross-section that are sensitive to gluon saturation.

## WG2 Small-x, Diffraction and Vector Mesons / 110

### Exclusive photoproduction of quarkonium at the LHC energies within the color dipole approach

**Author:** Maria Beatriz Gay Ducati<sup>1</sup>

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Recent results for the coherent photoproduction of vector mesons  $\psi(1S)$ ,  $\psi(2S)$  and Upsilon (1S) in the hadron-hadron and nucleus-nucleus collisions in the LHC energies are presented. Predictions for the rapidity distributions are obtained using the color dipole formalism and including saturation effects, expected to be relevant at high energies. Comparison is done to the  $J/\psi$  and  $\Psi(2S)$  photoproduction data from LHCb Collaboration on proton-proton collisions at 7 TeV and data from ALICE collaboration on lead-lead reactions at 2.76 TeV. Predictions are performed for the Upsilon states in proton and nucleus target.

## WG3:Electroweak Physics and Beyond the Standard Model / 111

### WA Fusion at Super-TeV Hadron Colliders

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<sup>2</sup> University of Pittsburgh

Vector boson fusion processes become increasingly more important at higher collider energies and for probing larger mass scales due to collinear logarithmic enhancements of cross sections. We consider the specific case of WA fusion at hadron colliders, and systematically categorize the contributions from an initial state photon in the elastic, inelastic, and deeply inelastic channels. Scale dependence of the matching scheme is addressed. Application to the production of a hypothetical heavy Majorana neutrino at the 14 TeV LHC and 100 TeV VLHC is briefly discussed.

## WG2 Small-x, Diffraction and Vector Mesons / 112

### Rapidity evolution of gluon TMD from low to moderate x

**Authors:** Andrey Tarasov<sup>1</sup>; Ian Balitsky<sup>2</sup>

<sup>1</sup> Jefferson Lab

<sup>2</sup> ODU/JLab

A TMD factorization generalizes the usual concept of parton density by allowing PDFs to depend on intrinsic transverse momenta in addition to the usual longitudinal momentum fraction variable. The available analysis of TMD evolution is mostly restricted to the evolution of quark TMDs at moderate  $x$ . However at high collider energies the majority of produced particles will be small- $x$  gluons. In this case one has to understand transition between this two limits. In the talk we will study how the rapidity evolution of gluon transverse momentum dependent distribution changes from nonlinear evolution at small  $x \ll 1$  to linear double-logarithmic evolution at moderate  $x \sim 1$ .

#### WG1 Structure Functions and Parton Densities / 113

### Nuclear Parton Distributions and Applications to Drell-Yan and anti-neutrino Scattering

**Authors:** Roberto Petti<sup>1</sup>; Sergey Kulagin<sup>2</sup>

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We study the nuclear parton distribution functions [1] on the basis of our recently developed semi-microscopic model [2], which takes into account a number of nuclear effects including nuclear shadowing, Fermi motion and nuclear binding, nuclear meson-exchange currents and off-shell corrections to bound nucleon distributions.

We discuss in details the dependencies of nuclear effects on the type of parton distribution (nuclear sea vs. valence) as well as on the parton flavour (isospin).

We apply the resulting nuclear parton distributions to calculate ratios of cross sections for proton-induced Drell-Yan production off different nuclear targets.

We obtain a good agreement on the magnitude, target and projectile  $x$  and the dimuon mass dependence of proton-nucleus Drell-Yan process data from the E772 [3] and E866 [4] experiments at Fermilab.

We also provide nuclear corrections for the Drell-Yan data from the E605 experiment.

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[3] D.M. Alde et al., Phys. Rev. Lett. **64** (1990) 2479

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#### WG2 Small- $x$ , Diffraction and Vector Mesons / 114

### Measurement of central exclusive $\pi^+\pi^-$ production in $p$ - $\bar{p}$ collisions at $\sqrt{s} = 0.9$ and 1.96 TeV at CDF

**Author:** Michael Albrow<sup>1</sup>

<sup>1</sup> *Fermi National Accelerator Laboratory*

We measure exclusive  $\pi^+\pi^-$  production in proton-antiproton collisions at center-of-mass energies  $\sqrt{s} = 0.9$  and 1.96 TeV in the Collider Detector at Fermilab. We select events with two oppositely charged particles, assumed to be pions, with pseudorapidity  $|\eta| < 1.3$  and with no other particles detected in  $|\eta| < 5.9$ . We require the  $\pi^+\pi^-$  system to have rapidity  $|y| < 1.0$ . The production mechanism of these events is expected to be dominated by double pomeron exchange, which constrains the quantum numbers of the central state. The data are potentially valuable for isoscalar meson spectroscopy, and for understanding the pomeron in a region of



transition between nonperturbative and perturbative quantum chromodynamics. The data extend up to dipion mass 5000 MeV/c<sup>2</sup>, and show resonance structures attributed to f<sub>0</sub> and f<sub>2</sub>(1270) mesons. From the pi+pi- and K+K- spectra we place upper limits on exclusive chi\_c0(3415) production.

## WG6 Spin Physics / 115

### Probing the Sea-Quark Contribution to Total Proton Spin via the Weak Interaction at PHENIX

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Over the past ten years, the RHIC spin program has deepened our knowledge of proton spin structure as part of a worldwide effort to solve the proton spin puzzle. While we now precisely understand the contribution of valence quarks to the total proton spin, large uncertainties still dominate the predictions describing the contributions of the sea of anti-up and anti-down quarks. In 2013, PHENIX accumulated  $277\text{pb}^{-1}$  of longitudinally polarized proton-proton collisions at  $510\text{GeV}$  in its full vertex acceptance. This data set is the culmination of a multi-year experimental effort to study the proton sea-quark polarization. From these collisions, we inclusively measure the  $W$  to lepton decay and probe the sea-quark helicities via the calculation of the longitudinal single spin asymmetries. Sea-quark helicities may be flavor separated via the charge of the  $W$  and decaying leptons, plus knowledge of the valence quark helicities. This method offers the advantage of giving clean access to the sea-quark helicities, in contrast to other methods which must deal with fragmentation. The measurement is carried out via the  $W \rightarrow \mu$  channel in PHENIX's forward kinematic region, and via the  $W \rightarrow e$  channel in the central region. We present the unique challenges and approaches to the study of the forward and central data sets alongside our analysis progress and results in this talk.

## WG7 Future experiments / 116

### The EMC effect: upcoming experimental programs at Jefferson Lab

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The Jefferson Lab 12 GeV upgrade ensures the continuation of experimental programs dedicated to the understanding of nuclear medium modifications of the quark and gluon structure of the nucleon. The origin of the EMC effect is still a matter of controversy thirty years after its initial observation. The path forward in achieving a conclusive understanding of how the medium modifications of the nucleon structure arise involves both experimental and theoretical efforts. I will discuss upcoming experiments at Jefferson Lab that focus on the exploration of the EMC effect origin by studying its quark flavor dependence, its signature in terms of the spin make-up of the nucleon substructure as well as its dependence on quantities such as mass, nuclear density, or even the relative probability of finding a Short Range Correlation (SRC) in the nucleus.

## WG1 Structure Functions and Parton Densities / 117

## Initial conditions for the double parton distribution functions

**Authors:** Anna Stasto<sup>1</sup>; Emilia Lewandowska<sup>2</sup>; Krzysztof Golec-Biernat<sup>3</sup>; Zachary Snyder<sup>1</sup>

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We demonstrate the mathematical formalism for the construction of the consistent initial conditions for the double parton distribution functions in the collinear approximation. The initial conditions within this framework have an important property that they satisfy exactly simultaneously both the momentum sum rules and the quark sum rules and are at the same time related to the single parton distribution functions. We find that this condition imposes certain relations on the large and small  $x$  behavior of both single and double parton distribution functions. We illustrate the double parton correlations for the gluon channel and show how they change with the evolution scale. Possible phenomenological implications are discussed.

**WG4 QCD and Hadronic Final States / 118**

## Measurement of soft photon collective flow in $\sqrt{s_{NN}}=200\text{GeV}$ Au+Au collisions at RHIC-PHENIX

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Direct photons are very interesting probes because they are not modified once created and emitted during all stages of the collisions.

Especially soft photons have been actively measured to study the hot and dense medium (QGP) created in high energy heavy ion collisions.

It is expected that direct photons have different angular emission patterns depending on their production mechanisms.

Previous PHENIX results indicate that photons have non-zero and positive  $v_2$  at low momentum, and the strength of  $v_2$  is comparable to that of hadrons at around 2 GeV/c.

The photon production mechanisms in low  $p_T$  region have not been well understood, and measurement of third order azimuthal anisotropy ( $v_3$ ) is expected to provide additional information to constrain the production mechanisms.

In this talk, we will discuss the recent PHENIX results on centrality dependence of the photon  $v_2$  and  $v_3$  in  $\sqrt{s_{NN}}=200$  GeV Au+Au collisions at RHIC-PHENIX.

**WG6 Spin Physics / 119**

## Exclusive meson production at COMPASS

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Hard exclusive lepton production of mesons on nucleons has played an important role in studies of the hadron structure and recently gained a renewed interest as it allows an access to generalised parton distributions (GPDs). The GPDs provide a novel and comprehensive description of the nucleon partonic structure and contain a wealth of new information. In particular, the GPDs give a description of the nucleon as an extended object, referred to as the three-dimensional nucleon tomography, and give an access to the orbital angular momentum of quarks. The exclusive meson production is sensitive to various types of the GPDs for different flavours depending on a quark content and quantum numbers of the meson ( $\rho^0$ ,  $\omega$ ,  $\pi^0$ , ...).

In this talk we will summarise recent measurements of the exclusive vector meson production performed by the COMPASS Collaboration. In particular, recent results on single-spin and double-spin asymmetries for the exclusive  $\rho^0$  and  $\omega$  production measured on a transversely polarised proton target will be presented. Some of these asymmetries are sensitive to the GPDs  $E$ , which are related to the orbital angular momentum of quarks. Other asymmetries are sensitive to the chiral-odd GPDs  $H_T$ , which are related to the transversity PDF distributions. Note, that our results for the  $\rho^0$  mesons provide the first experimental evidence from the hard exclusive vector meson production for the existence of non-vanishing GPDs  $H_T$ . In addition, the results for the  $\omega$  mesons, that will be shown for the first time at this conference, are sensitive to the pion pole contribution to the production mechanism. The future measurements of the hard exclusive meson production at COMPASS will be also discussed.

**WG6 Spin Physics / 120**

## Overview of the collinear twist-3 factorization for spin asymmetries

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In this talk, I will present an overview on the current status of the analyses of the spin asymmetries, in particular, single spin asymmetries, using the framework of the collinear twist-3 (CT3) factorization.

In this framework, twist-3 quark-gluon or three-gluon correlation functions in the initial nucleon and the twist-3 fragmentation function for the final hadron play a critical role as a source of the asymmetries. I will summarize the formalism and the characteristics features of the analyses. Though this mechanism is designed for the description of the spin asymmetries in the region of the large transverse momentum  $P_T$  of the final hadron, it also provides the asymmetries at lower  $P_T$  which is consistent with the transverse-momentum-dependent (TMD) factorization. Some of the functions in the CT3 and TMD factorizations are related to each other by the QCD equation of motion, which allows us to perform a global analysis of the spin asymmetries including both low  $P_T$  and large  $P_T$  data. I will summarize these features of the CT3 factorization.

**WG3:Electroweak Physics and Beyond the Standard Model / 121**

## Dark photon search with neutral meson decays at the PHENIX experiment

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A “dark photon” has been proposed as a hypothetical U(1) gauge boson in the dark sector. The dark photon is weakly coupled with ordinary photons and can explain several experimental results which can not be described by the standard model such as the excess of high energy positrons in cosmic rays and the muon g-2 anomaly. The PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) has performed a search for electron pairs from dark photons coupling to standard model photons in Dalitz decays of the  $\pi^0$  and  $\eta$ . An upper limit of the dark photon mixing strength with ordinary photons has been obtained for  $30 < m_U < 90 \text{ MeV}/c^2$ . We will present our latest result of the dark photon search in this talk.

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## Neutrino and anti-neutrino inelastic cross-sections with nuclei

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We discuss the current status in the calculation of high-energy neutrino and anti-neutrino inelastic scattering off nuclei in terms of nuclear structure functions. We present calculations of differential cross sections for inclusive neutrino and anti-neutrino scattering in comparison with recent data on different target materials. We discuss similarities and dissimilarities in the calculation of nuclear effects for charged-lepton and (anti)neutrino scattering caused by a non-conserved axial current in neutrino scattering.

WG4 QCD and Hadronic Final States / 123

## Jet measurements, $\alpha_s$ and PDF results from CMS

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We present recent jets results from CMS at a centre of mass energy of 7 and 8 TeV. The impact of those data on the precise measurement of the QCD parameters is studied.

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## Top quark mass measurements with CMS

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Measurements of the top quark mass are presented, obtained from CMS data collected in proton-proton collisions at the LHC at centre-of-mass energies of 7 TeV and 8 TeV. The mass of the top quark is measured using several methods and channels, including the reconstructed invariant mass distribution of the top quark, an analysis of endpoint spectra as well as measurements from shapes of top quark decay distributions. The dependence of the mass measurement on the kinematic phase space is investigated. The results of the various channels are combined and compared to the world average. The top mass and also  $\alpha_s$  are extracted from the top pair cross section measured at CMS.

WG3+WG5 Joint Session / 125

## Measurements of the top-quark properties in the production and decays of $t\bar{t}$ events at CMS and ATLAS

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Measurements of several top-quark properties are presented, obtained from the CMS data collected in 2011 and 2012 at centre-of-mass energies of 7 and 8 TeV. The results include measurements of the top pair charge asymmetry, the W helicity in top decays, the top quark charge, and of the  $t\bar{t}$  spin correlation and the search for anomalous couplings. The results are compared with predictions from the standard model as well as new physics models. The cross section of  $t\bar{t}$  events produced in association with a W, Z boson or a photon is also measured.

The top quark pair charge asymmetry is an asymmetry predicted to occur beyond leading-order QCD in the Standard Model, and may be significantly enhanced by the presence of new physics. The  $t\bar{t}$  production charge asymmetry is measured inclusively and differentially using the 7 and 8 TeV ATLAS datasets. Making use of the large number of top quark pairs collected, we also present measurements of the spin correlation between top and anti-top quarks using several variables and discuss their sensitivity to new physics. A search for flavour changing neutral current processes in top quark decays is also presented.

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## Single top quark production with CMS

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Measurements of single top quark production are presented, performed using CMS data collected in 2011 and 2012 at centre-of-mass energies of 7 and 8 TeV. The cross sections for the electroweak production of single top quarks in the t-channel and in association with W-bosons is measured and the results are used to place constraints on the CKM matrix element  $V_{tb}$ . In the t-channel the ratio of top and anti-top production cross sections is determined and compared with predictions from different parton density distribution functions. Measurements of top quark properties in single top quark production are also presented. The results include the W-helicity in top quark decay and the searches for s-channel production and for anomalous couplings.

WG3:Electroweak Physics and Beyond the Standard Model / 127

## W/Z results from CMS

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The production of W and Z bosons has been observed in pp collisions at a center-of-mass energy of 7 and 8 TeV using data collected in the CMS experiment. W events were selected containing an isolated, energetic electron or muon. Z events were selected containing a pair of isolated, energetic electrons or muons. Data-driven methods are used to estimate reconstruction and triggering efficiencies, and well as the main backgrounds. The recent CMS results are presented.

WG3+WG5 Joint Session / 129

## Vector boson production in association with jets and heavy flavor quarks with CMS

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The production of vector bosons ( $V = W, Z$  or  $\gamma$ ) in association with jets is a stringent test of perturbative QCD and is a background process in searches for new physics. Total and differential cross-section measurements of vector bosons produced in association with jets and heavy flavour quarks in proton-proton collisions at the LHC are presented. The measurements are compared to next-to leading order calculations and event simulations that devise matrix element calculations interfaced with parton showers.

WG3:Electroweak Physics and Beyond the Standard Model / 130

## Search for an additional Higgs-like boson decaying to WW or ZZ in the mass range 145 to 1000 GeV

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A search for additional Higgs-like bosons in the H to WW and H to ZZ decay channels is reported, for Higgs boson masses in the range  $145 < m_H < 1000$  GeV. The search is based upon proton-proton collision data samples corresponding to an integrated luminosity of up to  $5.1 \text{ fb}^{-1}$  at  $\sqrt{s} = 7$  TeV and up to  $19.3 \text{ fb}^{-1}$  at  $\sqrt{s} = 8$  TeV, recorded by the CMS experiment at the LHC. Several final states of the H to WW and H to ZZ decays are analyzed. Upper limits for the search for a heavy resonance in the context of an electroweak singlet extension of the standard model are presented. Additionally, the combined upper limits at 95% confidence level on the products of the cross section and branching fraction exclude a standard-model-like Higgs boson in the range  $145 < m_H < 1000$  GeV

WG5 Heavy Flavours / 132

## Top quark cross section measurements with CMS

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Measurements of the inclusive top quark pair production cross section at 7 TeV and 8 TeV are presented, performed using CMS data collected in 2011 and 2012. The total cross section is measured in the lepton+jets, dilepton and fully hadronic channels, including the tau-dilepton and tau+jets modes.

Indirect constraints on both the top quark mass and  $\alpha_s$  are obtained through their relation to the inclusive cross section. First measurements of top quark pair production with additional b-quarks in the final state are also presented. Differential cross sections are measured and are given as functions of various kinematic observables, including the transverse momentum and rapidity of the (anti)top quark and the top-antitop system and the jets and leptons of the event final state. Multiplicity and kinematic distributions of the jets produced in addition to the top pair are also investigated. The results are combined and confronted with precise theory calculations.

**WG7 Future experiments / 133**

## The Evolution Of PHENIX Into An Electron Ion Collider (EIC) Experiment

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The Electron Ion Collider (EIC, arXiv:1212.1701.v3) will allow for precision measurements of the partonic and spin structure of nucleons and the partonic structure of nuclear matter using e+p and e+A collisions, respectively. One of the realizations of the EIC, the eRHIC at BNL, plans to utilize the existing RHIC storage rings (polarized proton and other ion beams) and a high-intensity polarized electron facility to be built in the RHIC tunnel. Before the transition to eRHIC, RHIC itself still holds a huge potential for study leading to new insights into hadronic spin structure and cold nuclear matter with p+p and p+A collisions. An experiment based on the BaBar solenoid with barrel calorimeters and tracking detectors (sPHENIX, arXiv:1207.6378v2) and additional instrumentation in the proton-going direction (fsPHENIX) would realize this potential. By design, this detector is planned to smoothly evolve into a full-fledged EIC experiment at eRHIC with additional calorimeters, tracking, and particle identification systems (arXiv:1402.1209). We give an overview of the experiment in its RHIC and eRHIC stages, the respective physics goals, and detector simulations.

**WG2 Small-x, Diffraction and Vector Mesons / 134**

## Diffraction production from the Color-Glass-Condensate

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I will discuss that diffractive production at small-x, including diffractive photo production of vector mesons and dijet can be a powerful probe of non-linear gluon-saturation dynamics [1,2]. In particular, I will focus on the diffractive dijet production at HERA and the LHC within the color-glass-condensate approach [2]. I will show that the t-distribution of photoproduction of dijet and vector mesons at large |t| offers a unique opportunity to discriminate among saturation and non-saturation models. I will also show that diffractive dijet correlations at small-x exhibit some non-trivial novel features which are different from the inclusive two-particle correlations, like inclusive dijet, dihadron [3], diphoton [4] and photon-hadron [5] productions. Therefore, diffractive dijet photo-production at the LHC and future colliders provides useful complementary information about the underlying dynamics of particle production in the saturation regime.

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- 4: A. Kovner and A. H. Rezaeian, Phys. Rev. D 90, 014031 (2014).
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## WG6 Spin Physics / 135

### Recent COMPASS results on transverse spin asymmetries in SIDIS.

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Recent results on the transverse spin azimuthal asymmetries in semi-inclusive DIS reactions extracted by the COMPASS Collaboration from the data collected with a transversely polarised proton target are presented.

In particular, the interesting kinematical dependencies shown by the Collins and Sivers asymmetries have been further investigated in a multi-dimensional analysis in  $x$ ,  $Q^2$ ,  $z$  and  $p_T$ .

Moreover, the similarity between the Collins asymmetries and the dihadron asymmetries recently observed by COMPASS has been further investigated for an event sample containing at least a pair of oppositely charged hadrons. From the dependence of the asymmetries on the azimuthal angle between the two detected hadrons a quantitative relation between the two asymmetries is derived, confirming the original suggestion that a common physical mechanism underlies the two mechanisms

## WG6+WG7 joint session / 136

### Polarized Drell-Yan measurements at Fermilab: The future of the SeaQuest experiment

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The SeaQuest experiment at Fermilab continues a series of Drell-Yan measurements to explore the antiquark content of the nucleon and to study the modifications to the nucleon structure when the nucleon is embedded into a nuclei. To extend existing measurements to larger values of Bjorken- $x$ , a 120 GeV proton beam extracted from Fermilab's main injector is used, resulting in 50 times more luminosity than previous experiments and enabling access to values of  $x$  up to 0.9.

A brief overview will be presented of the key physics goals of the SeaQuest collaboration: These include investigation of the dramatic  $d$ bar/ $u$ bar flavor asymmetry in the nucleon sea and its behavior at high  $x$ ; study of the EMC effect in Drell-Yan scattering and the unexpected absence of any antiquark excess in existing data; and measurements of the angular dependence of the Drell-Yan process, sensitive to spin-orbit correlations within the nucleon. A status report on the ongoing data taking and analysis of this new experiment will be given.



The focus of the talk will be on the SeaQuest upgrades with polarized target (E-1039) and polarized beam (E-1027). Polarized Drell-Yan measurements are the missing component in the global analysis of transverse-momentum-dependent PDF (TMD) and will provide complementary information to existing data from semi-inclusive DIS. The SeaQuest upgrade with polarized target will allow a first measurement of the Sivers TMD for sea quarks; the upgrade with polarized beam will allow to constrain the sign, size, and maybe the shape of the Sivers TMD for valence quarks.

#### WG1 Structure Functions and Parton Densities / 137

### Constraining Sea Quark Distributions Through $W^\pm$ Cross Section Ratios Measured at STAR

**Author:** Matthew Posik<sup>1</sup>

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Over the past several years the STAR experiment at RHIC has been contributing to our understanding of the proton structure. Through proton-proton collisions, STAR is well equipped to measure the  $e^\pm$  leptonic decays of  $W^\pm$  bosons in the mid-rapidity region ( $-1.1 \leq \eta \leq 1.1$ ) at  $\sqrt{s} = 500/510$  GeV. The  $W$  cross section ratio ( $W^+/W^-$ ) is sensitive to unpolarized  $u$ ,  $d$ ,  $\bar{u}$ , and  $\bar{d}$  quark distributions. At these kinematics STAR is able to measure the quark distributions near Bjorken- $x$  of 0.1. The RHIC runs in 2012 and 2013 at  $\sqrt{s} = 500/510$  GeV saw a significant increase in delivered luminosity from previous years. This resulted in using data samples of about 80 and 250  $\text{pb}^{-1}$  of integrated luminosity, respectively. The increased statistics will lead to a higher precision measurement of the  $W^+/W^-$  cross section ratio as well as its  $\eta$  dependence at mid-rapidity. Presented here is an update of the  $W$  cross section ratio analysis from the STAR 2012 and 2013 runs.

#### WG2 Small- $x$ , Diffraction and Vector Mesons / 138

### CGC beyond eikonal accuracy

**Author:** Tolga Altinoluk<sup>1</sup>

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We present a new method to systematically calculate corrections to the eikonal approximation in the background field formalism. We calculate the subleading power-suppressed corrections due to the finite width of the target to first and second orders. The method is of generic applicability. As a first example, we study both polarized and unpolarized gluon production in pA collisions.

#### WG6 Spin Physics / 139

### Recent Results of Semi-inclusive DIS Experiments at Jefferson Lab

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Semi-inclusive deep inelastic scattering (SIDIS) is a powerful tool to explore the 3-d structure of nucleon in momentum space. Through a combination of polarized/unpolarized lepton beam and nucleon target one can study various transverse-momentum dependent parton distribution functions (TMDs) that appear in the SIDIS cross-section. TMDs provide a description of nucleon structure in terms of parton's transverse momentum and its transverse spin, which enables us to study the quark orbital angular momentum effects in the nucleon. Several SIDIS experiments were performed in three Halls at Jefferson Lab with 6 GeV electron beam using both polarized/unpolarized beam and target combinations. The kinematic range was mainly focused on valence quark region. We will present some recent results from Jefferson Lab 6 GeV run and discuss future plans after the 12 GeV upgrade.

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## QCD corrections to the electroweak top-pair production beyond the Standard Model

**Author:** Tomas Jezo<sup>1</sup>

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We discuss the calculation of next-to-leading order QCD corrections to the electroweak top-pair production in the extensions of the Standard Model predicting an additional heavy neutral spin-1 resonance  $Z'$ . Compared to previous studies we implement our calculation in the POWHEG BOX V2 framework allowing for consistent matching of NLO QCD computations with the parton shower.

WG6 Spin Physics / 142

## Constraining Transversity and Nucleon Transverse-polarization Structure Through Polarized-proton Collisions at STAR

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Current knowledge of nucleon transverse-polarization structure comes from measurements of transverse single-spin asymmetries (SSAs) from semi-inclusive deep inelastic scattering (SIDIS). These measurements, combined with those of  $e^+e^-$  collisions, have allowed the first extraction of transversity with limited constraints at higher values of Bjorken- $x$ . One avenue to enrich understanding over a different kinematic range is jet+hadron and di-hadron production from polarized-proton collisions. Through these channels, the STAR detector at RHIC has for the first time observed SSAs due to the effects of transversity coupled to the Collins and interference fragmentation functions (IFFs) in polarized-proton collisions at  $\sqrt{s} = 200$  and 500 GeV. In addition to transversity, the distribution of pions within jets may also provide a window into gluon linear polarization. Furthermore, the comparison of all asymmetry moments at 200 GeV and 500 GeV may yield insight into longstanding theoretical questions concerning evolution, universality, and factorization breaking in non-collinear formulations of pQCD. Preliminary results from the jet+hadron and di-hadron analyses at  $\sqrt{s} = 200$

and 500 GeV will be presented, including the first observations of transversity effects in polarized-proton collisions and the first-ever measurements offering constraints on models involving gluon linear polarization.

### WG3:Electroweak Physics and Beyond the Standard Model / 143

## The WW story

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Run 1 of the LHC has reported routine excesses in WW measurements both at 7 and 8 TeV. I shall demonstrate that accounting for higher order QCD effects through pT resummation can account for some of the differences between theory and experiment. A closely related approach; jet veto resummation has also had success explaining this excess. I will also talk about where these methods agree and disagree and how experimentally these effects could be tested.

### WG2 Small-x, Diffraction and Vector Mesons / 144

## The perturbative Pomeron with NLO accuracy: Jet-Gap-Jet Observables

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We present the results for the calculation of the forward jet vertex associated to a rapidity gap (coupling of a hard pomeron to the jet) in the Balitsky-Fadin-Kuraev-Lipatov (BFKL) formalism at next-to-leading order (NLO). We handle the real emission contributions making use of the high energy effective action proposed by Lipatov, valid for multi-Regge and quasi-multi-Regge kinematics. This result is important since it allows, together with the NLO non-forward gluon Green function, to perform NLO studies of jet production in diffractive events (Mueller-Tang dijets, as a well-known example).

### WG4 QCD and Hadronic Final States / 145

## NLO+PS for coloured-resonance mediated processes

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**Co-authors:** Carlo Oleari<sup>1</sup>; Tomas Jezo<sup>2</sup>

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We discuss the subject of matching the NLO QCD corrections to the parton shower for processes mediated by coloured resonances. In order to perform precise realistic simulations of the production of resonances their decay must be included. In current frameworks for NLO+PS simulations, however, problems arise when generating the radiation from the decay of the resonance, especially for narrow resonances. We outline steps towards a future consistent prescription for a framework for matching of NLO calculations involving intermediate resonances decaying into coloured particles with parton showers that fully accounts for finite width and interference effects.

**WG1 Structure Functions and Parton Densities / 146**

## On the of physical DGLAP evolution of structure functions and its use for detecting saturation effects

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We revive the idea of using physical anomalous dimensions in the QCD scale evolution of deep-inelastic structure functions and their scaling violations and present a detailed phenomenological study of its applicability up to NNLO. In particular we are interested in the use of physical DGLAP evolution as a tool to detect possible deviations from linear DGLAP evolution at small  $x$  which signal the onset of a non-linear regime, characterized by large and saturated parton densities. Such applications are of particular interest for future DIS experiments such as the LHeC and EIC projects, which aim at a detailed study of the transition of the dilute DGLAP regime to the saturated, nonlinear regime which is expected to manifest itself at small  $x$  and/or large nuclei.

**WG6+WG7 joint session / 147**

## Highlights from the (un)polarized e+p scattering program at an EIC

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Our understanding of the structure of nucleons is described by the properties and dynamics of quarks and gluons in the theory of quantum chromodynamics. With advancements in theory and the development of phenomenological tools we are preparing for the next step in subnuclear tomographic imaging at a future electron-ion collider. High center-of-mass energies ( $\sqrt{s} \approx 45 - 150$  GeV) in combination with extremely high luminosities ( $10^{33-34}$  cm<sup>-2</sup>s<sup>-2</sup>) will provide the precision and a kinematic reach well into the gluon dominated regime. Highly polarized nucleon and electron beams ( $P_{beam} \approx 70$ )

**WG1 Structure Functions and Parton Densities / 148**

## Measurement of Neutrino Induced Resonance Production

**Authors:** Hongyue Duyang<sup>1</sup>; Roberto Petti<sup>2</sup>; Sanjib Mishra<sup>2</sup>; Xinchun Tian<sup>2</sup>

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Resonance interaction is one of the most important neutrino interaction modes for neutrino oscillation experiments in the few-GeV energy region. This talk presents the analysis of resonance production in neutrino charged current interaction. The study is extended to the NOMAD data allowing the most precise neutrino resonance measurement to date. Some of the current discrepancies in the resonance measurements are addressed, and future prospects outlined. The analysis includes the simulation studies in future next generation neutrino scattering experiments.

**WG2 Small-x, Diffraction and Vector Mesons / 149**

## Coherent Rho Meson Production in Neutrino Interaction

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New measurements of coherent  $\rho^0$  and  $\rho^+$  production in NOMAD are reported. We present simulation of neutrino induced coherent  $\rho$ -meson production in charged and neutral current interactions. Sensitivity studies of this process for next generation neutrino scattering experiments is presented.

**WG6 Spin Physics / 150**

## Measurement of longitudinal single-spin asymmetries for $W^\pm$ boson production in polarized $p + p$ collisions at $\sqrt{s} = 510$ GeV at STAR

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$W^\pm$  boson production in longitudinally polarized  $p + p$  collisions provides unique and clean access to the individual helicity polarizations of  $u / d$  quarks and anti-quarks. Due to maximal violation of parity,  $W$  bosons couple to left-handed quarks and right-handed anti-quarks and hence offer direct probes of their respective helicity distributions in the nucleon. These can be extracted from measured parity-violating longitudinal single-spin asymmetries,  $A_L$ , for  $W^{-(+)}$  boson production as a function of decay lepton (positron) pseudo-rapidity  $\eta$ . The STAR experiment is well equipped to measure  $A_L$  for  $W^{-(+)}$  boson production between  $|\eta| < 1$ .

The published STAR  $A_L$  results (combination of 2011 and 2012 data) have been used by several theoretical analyses

suggesting a significant impact in constraining the helicity distributions of anti- $u$  and anti- $d$  quarks. In 2013 the STAR experiment has collected a large data sample of  $\sim 250 \text{ pb}^{-1}$  which is more than 3 times larger than the total integrated luminosity in 2012, at  $\sqrt{s} = 510 \text{ GeV}$  with an average beam polarization of  $\sim 54\%$ , comparable to run 2012. The status of the 2013  $A_L$  analysis will be discussed along with an overview of future plans.

## WG6 Spin Physics / 151

### Charged kaon multiplicities in semi-inclusive deep-inelastic scattering from COMPASS

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The latest measurements of  $K^\pm$  multiplicities in semi-inclusive deep-inelastic scattering from the COMPASS experiment at CERN are presented. The data were collected using a  $160 \text{ GeV}$  muon beam incident on an isoscalar  ${}^6\text{LiD}$  target. The large statistics collected cover a wide kinematic range and the results are presented in 3-dimensional bins of  $x_{Bjorken}$ ,  $y$ , and  $z$ . These measurements are sensitive to both the strange quark distribution function  $s(x)$  and to the strange quark fragmentation functions. They will serve as inputs to global QCD fits to constrain quark fragmentation functions.

## WG3:Electroweak Physics and Beyond the Standard Model / 152

### Production of W bosons in p-Pb collisions measured with ALICE at the LHC.

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by E.Z. Buthelezi for the ALICE collaboration,  
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W bosons are produced in hard scattering processes of partons in collisions of hadrons and they do not interact strongly with the medium produced in high-energy heavy-ion collisions. Therefore, in p-Pb collisions the measurement of W-boson yields represents a standard candle to check the validity of binary-collision scaling and can provide important constraints on the parton distribution functions, which can be modified in nuclei with respect to protons or neutrons.

At the LHC, ALICE (A Large Ion Collider Experiment) is dedicated to the study of ultra-relativistic heavy-ion collisions, in which a hot and dense strongly-interacting medium is formed. At forward rapidities ALICE is equipped with a muon spectrometer that allows measurements of dimuon decays of quarkonia, muons from heavy-flavour hadron decays and also W bosons via their single-muon decay. In ALICE W-boson cross sections were measured in p-Pb collisions at  $\sqrt{s_{NN}} = 5.02 \text{ TeV}$  via the contribution of their muonic decays to the inclusive  $p_T$ -differential muon yield measured at forward ( $2.03 < y_{\text{cms}} < 3.53$ ) and backward rapidity ( $-4.46 < y_{\text{cms}} < -2.96$ ) in various event-activity intervals. Recent results obtained from these measurements will be presented and the measured cross sections will be compared to perturbative Quantum Chromodynamics calculations at next-to-leading order.

## WG6 Spin Physics / 153

**PHENIX Results of Transverse Single-Spin Asymmetries in  $\eta$  and single-muon production channels in  $p^\uparrow + p$  collision****Author:** Kenneth Barish<sup>1</sup><sup>1</sup> *UC Riverside***Corresponding Author:** kenneth.barish@ucr.edu

(for the PHENIX Collaboration)

Transverse single-spin asymmetries (TSSA) provide valuable information about the spin structure of the nucleon. Here, we report results of TSSA in  $\eta$  and single-muon production channels in  $p+p$  collision. Non-vanishing TSSA in eta meson production channel has been reported for Run-2008 data (Phys. Rev. D 90, 072008), in the forward rapidity region, which could be due to contributions from both the Sivers and the Collins effects. In single-muon production channel, gluon-gluon fusion dominates heavy-flavor meson production, which in turn provides the dominate source of high momentum single-muons. Therefore, TSSA of single-muon production provide an unique probe to access information on the gluon Sivers distribution. In Run-2012, the PHENIX experiment collected data of  $9.2 \text{ pb}^{-1}$  integrated luminosity in transversely polarized  $p + p$  collisions at  $\sqrt{s} = 200 \text{ GeV}$  with a polarization of 60%. The status and preliminary results of the analysis of transverse single-spin asymmetries of single muons at forward-rapidity will be presented.

## WG5 Heavy Flavours / 154

**PHENIX heavy-flavor results in  $d+\text{Au}$  collisions****Author:** Sanghoon Lim<sup>1</sup><sup>1</sup> *Yonsei University***Corresponding Author:** shlim1986@gmail.com

Charm and bottom quarks are formed predominantly by gluon fusion in the initial hard scatterings of heavy-ions at RHIC, so they are good probes of the full medium evolution. In order to further understand the heavy quark dynamics in the hot medium, it is essential to study modifications due to the intrinsic nuclear matter so called cold nuclear matter effects. Deuteron(proton)-gold collisions are considered as a control experiment to study this kind of effects, but recent results from central  $d(p)+\text{A}$  collisions also suggest formation of a small thermalized system. The PHENIX experiment has an excellent ability to measure leptons decaying from charm/bottom hadrons at wide kinematic range. These results will be key measurement to understand evolution of medium effects from  $p+p$  collisions to heavy-ion collisions. In this talk, measurements of heavy quark production from  $p+p$  and  $d+\text{Au}$  collisions in PHENIX will be presented and discussed with several model calculations.

## WG1 Structure Functions and Parton Densities / 155

**Extracting the  $d/u$  ratio with the Self Organizing Maps Algorithm****Author:** Simonetta Liuti<sup>1</sup><sup>1</sup> *University of Virginia*

**Corresponding Author:** sl4y@virginia.edu

I will discuss the application of an alternative type of neural network, the Self-Organizing Maps (SOMs), to extract parton distribution functions from various hard scattering processes. SOMs provide a complementary algorithm to NNPDFs yielding a parametrization that is free from the bias implicit in choosing specific analytic forms. At the same time it enables us to extrapolate to kinematical regions where data are not available.

I will show in particular the extraction using SOMs of the ratio  $d/u$  in the  $x=1$  limit.

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## Extracting the $d/u$ ratio with the Self Organizing Maps Algorithm

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**WG2 Small-x, Diffraction and Vector Mesons / 157**

## Review of RENORM Diffractive Predictions for LHC up to 8 TeV and Extension to 13 TeV

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

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

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

Predictions of diffractive, total, and total-inelastic cross sections at the LHC, based on the pre-LHC renormalization model of diffraction RENORM, are reviewed and compared with the latest experimental results. RENORM is found to be in reasonable agreement with all aspects of the data and is extended to include predictions for the upcoming LHC run at 13 TeV.

**WG1 Structure Functions and Parton Densities / 158**

## Low Energy Beam Neutrino Nucleus Deep Inelastic Scattering at MINERvA

**Author:** Joel Mousseau<sup>None</sup>

**Corresponding Author:** joelam@fnal.gov

Neutrinos provide a unique probe of nuclear structure as they interact weakly and couple with partons via the axial as well as the vector current. The MINERvA experiment takes advantage of



the Fermilab NuMI beam line and multiple nuclear targets to study neutrino + nucleus interactions. This talk presents preliminary results of MINERvA's DIS sample in the neutrino energy ( $E_\nu$ ) range of 5 to 50 GeV, and a mean momentum-transfer squared ( $Q^2$ ) of 4.0 (GeV/c)<sup>2</sup>. Results will be presented as ratios of C, Fe and Pb to CH. The ratio of the total cross sections as a function of  $E_\nu$ , and differential cross sections as a function of Bjorken-x will be presented.

**WG7 Future experiments / 159**

## Physics Opportunities with Forward Detector Upgrades at STAR

**Author:** Zhenyu Ye<sup>1</sup>

<sup>1</sup> *University of Illinois at Chicago*

The STAR collaboration proposes to construct a Forward Calorimeter System and Forward Tracking System for future polarized p+p, polarized p+A, and A+A beam operations at RHIC. The main scientific goals are to study Quantum Chromo Dynamics (QCD) in the high and low Bjorken-x domain and to explore the properties of the strongly interacting Quark-Gluon Plasma (QGP). The proposed upgrades will allow measurements in polarized p+p collisions to improve our understanding of the spin and momentum-space parton distributions in the nucleon. Measurements in polarized p+A collisions will offer unique opportunities to study QCD dynamics in nuclei and to investigate the existence of non-linear evolution effects at high-gluon density. The proposed upgrade will also facilitate the determination of QGP properties in A+A collisions through improved measurements of the initial density fluctuations as well as the collective flow seeded by these fluctuations. In this talk, we will present the proposed forward detector upgrades and the exciting new physics opportunities that such upgrades will bring.

**WG5 Heavy Flavours / 160**

## Measurements of Open Heavy Flavor Production in Semi-leptonic Channels at STAR

**Author:** Zhenyu Ye<sup>1</sup>

<sup>1</sup> *University of Illinois at Chicago*

High precision measurements of open heavy flavor production in p+p collisions are instrumental to test the validity and constrain the parameters of perturbative QCD (pQCD) calculations. Heavy flavor quarks are also suggested as excellent probes to study the properties of the hot and dense nuclear matter created in high-energy heavy ion collisions. In this talk, we present the most recent results on open heavy flavor production through semi-leptonic decay channels from the STAR experiment at the Relativistic Heavy Ion Collider. An improved measurement on the Non-Photonic Electron (NPE) production from semi-leptonic decay of open heavy flavor hadrons in p+p collisions at  $\sqrt{s}=200$  GeV will be discussed and compared to pQCD calculations. Modification of NPE production yields and elliptic flow measured in Au+Au collisions at  $\sqrt{s_{NN}}=39, 62.4,$  and 200 GeV will also be presented and compared to theoretical model calculations.

**WG6 Spin Physics / 161**

## Recent fragmentation function measurements at Belle

**Author:** Anselm Vossen<sup>1</sup>

<sup>1</sup> *Indiana University*

Fragmentation functions are fundamental objects that describe the process by which partons hadronize to colorless hadrons.

Precision measurements of fragmentation functions are necessary for the extraction of most aspects of the nucleon structure from semi-inclusive deep inelastic scattering and p+p collision data.

Examples are transverse polarization dependent fragmentation functions that are needed to access the transverse spin structure of the proton and the measurement of the intrinsic transverse momentum dependence of unpolarized fragmentation functions that is needed to access non-collinear aspects of the nucleon structure.

Beyond providing crucial input for our studies of the partonic structure of the nucleon, fragmentation functions can also be used to study fundamental aspects of non-perturbative QCD, such as TMD evolution.

The cleanest access to fragmentation functions can be gained using e+e- annihilation data. The Belle experiment at KEK collected more than  $1 \text{ ab}^{-1}$  of data near the Upsilon(4S) resonance, several orders of magnitude more than was available before the start of the B-factories.

This talk will highlight recent results of the Belle fragmentation function measurement program and will give an outlook to future possibilities with the Belle II detector.

#### WG1 Structure Functions and Parton Densities / 162

### Fast re-evaluation of the W/Z differential cross-section at the NNLO using APPLGRID interface to DYNNLO framework

**Author:** Pavel Starovoitov<sup>1</sup>

<sup>1</sup> *Deutsches Elektronen-Synchrotron (DE)*

**Corresponding Author:** pavel.starovoitov@cern.ch

A method to facilitate the inclusion of collider data in the PDF fits, APPLGRID, has been extended to the NNLO accuracy. The method stores the matrix elements of the NNLO calculations to the look-up tables. This allows the a posteriori inclusion of the PDF sets and the strong coupling to the cross-section calculations.

#### WG3:Electroweak Physics and Beyond the Standard Model / 163

### Recent highlights from SUSY searches at CMS

**Corresponding Author:** denis.rathjens@cern.ch

Supersymmetry is one of the most thoroughly discussed extensions of the Standard Model, and is providing elegant solutions to fundamental questions like the nature of Dark Matter or the hierarchy problem. In this talk, recent results from the CMS experiment at the LHC on searches for supersymmetry are presented using  $20/\text{fb}$  of data from the 8 TeV LHC run. A variety of complementary final state signatures and methods are used to probe the production of supersymmetric particles, such as gluinos, squarks, sleptons, or electroweak superpartners. Prospects for LHC run 2 and beyond will be discussed.

#### WG3:Electroweak Physics and Beyond the Standard Model / 165

## Recent results from BSM Higgs searches and searches for new light bosons decaying into muon pairs with the CMS detector

**Corresponding Author:** marc.gabriel.weinberg@cern.ch

Several models of new physics predict the existence of new light bosons that are weakly coupled to SM particles. Two examples include SUSY with a “dark” sector (in which the new light bosons can also be relatively long-lived) or models with an extended Higgs sector, e.g. NMSSM. In these scenarios, the new bosons can be produced either in the Higgs decays or as part of SUSY cascades. In the presence of either non-SM Higgs couplings or of additional Higgs bosons, these decays could either hide the additional Higgs bosons from standard searches or alter the measured production rates in standard final states of the SM-like Higgs boson observed at the LHC. Direct searches for non-SM decays of the Higgs boson provide a complementary approach to SM Higgs searches and can help further understand the nature of Higgs boson by either confirming or rejecting large classes of BSM scenarios. We present the status and recent results of a search for a non-SM Higgs boson decaying to a pair of new light bosons, each of which subsequently decays into a boosted muon pair, using the LHC data collected by the CMS experiment.

WG2 Small-x, Diffraction and Vector Mesons / 166

## Diffraction processes in pp collisions at 7 TeV measured with the CMS experiment

**Corresponding Author:** grzegorz.brona@cern.ch

The differential diffractive cross section is measured as a function of  $x_i = M_X^2/s$  in the region dominated by single dissociation (SD) and double dissociation (DD), where  $M_X$  is the mass of one of the two final-state hadronic systems separated by the largest rapidity gap in the event. The cross section is also measured as a function of the width of the central rapidity gap in the region dominated by DD, as well as for events with a forward gap over 8.4 units of pseudorapidity. The total SD and DD cross sections are extracted. Single diffraction is one of the main uncertainties both, experimentally and in theoretical calculations, of the particle-production cross section in proton-lead collisions as measured at the centre-of-mass energy per nucleon pair of 5.02 TeV. Furthermore, the observation of a hard color-singlet exchange process in events with a large rapidity gap between two leading jets (jet-gap-jet) is reported. The fraction of jet-gap-jet to all dijet events is measured as a function of the second leading jet transverse momentum and the size of the pseudorapidity gap.

WG3:Electroweak Physics and Beyond the Standard Model / 167

## Multiboson measurements and Exclusive $W^+W^-$ production and constraints on Anomalous Quartic Gauge Couplings measured with the CMS experiment

**Corresponding Author:** jordan.damgov@cern.ch

A search for exclusive or quasi-exclusive  $W^+W^-$  production induced by photon-photon exchange in pp collisions at  $\sqrt{s}=8$  TeV is reported using data corresponding to an integrated luminosity of 19.7 fb<sup>-1</sup>. Events are selected by requiring the presence of an electron-muon pair with large transverse momentum  $p_T > 30$  GeV and no associated charged particles detected from the same vertex. The observed yields and kinematic distributions are compatible with the Standard Model prediction for exclusive and quasi-exclusive  $W^+W^-$  production. The dilepton transverse momentum spectrum is

studied for deviations from the Standard Model, and the resulting upper limits are compared to predictions assuming anomalous quartic gauge couplings.

**WG5 Heavy Flavours / 168**

## **Measurement of four-jet production including two heavy-flavour jets in pp collisions at 7 TeV with the CMS experiment**

**Corresponding Author:** paolo.gunnellini@cern.ch

Measurements of the differential cross sections for the production of at least four jets, two of them initiated by b-quarks, in proton-proton collisions are presented as a function of the transverse momentum  $p_T$  and pseudorapidity  $\eta$ , together with the correlations in azimuthal angle and the  $p_T$  balance among the jets. The data sample was collected in 2010 at a center-of-mass energy of 7 TeV with the CMS detector at the LHC with an integrated luminosity of 3pb<sup>-1</sup>. The measurement, compared to predictions from different models, shows that the addition of parton showers to fixed-order matrix element calculations describe the measured differential cross sections in only some regions of phase space. Including a contribution from double parton scattering in the models improves the predictions.

**WG4 QCD and Hadronic Final States / 169**

## **Testing QCD with jets measured by CMS down to very low- $p_T$ and into the forward phase space**

**Corresponding Author:** alex.baudouin.e.van.spillbeeck@cern.ch

Several measurements of QCD jets are presented as performed at different center-of-mass energies with the CMS experiment. By extending the measurement into the forward phase space and also towards low- $p_T$  the sensitivity to new features of QCD is maximised. The simultaneous observation of several jets in the same event is exploited to study for example the angular correlations of Mueller Navelet jet topologies in order to search for the signature of BFKL parton dynamics. But multi-jet measurements are also used to test higher-order QCD effects, and by lowering the jet  $p_T$  to the smallest possible values the minijet production close to the factorization limit is studied.

**WG4 QCD and Hadronic Final States / 170**

## **Bose-Einstein correlations in various collision systems and energies measured with the CMS experiment**

**Author:** Nicolo CMS Collaboration<sup>1</sup>

<sup>1</sup> Cartiglia

**Corresponding Authors:** cartiglia@to.infn.it, sandra.padula@cern.ch

Two-particle, quantum-statistical (Bose-Einstein) correlations are measured with the CMS experiment in pp collisions at 0.9, 2.76 and 7 TeV center-of-mass energies, as well as in pPb and peripheral PbPb collisions, respectively at 5.02 and 2.76 TeV center-of-mass energy per nucleon. The analysis is performed as a function of both the charged particle multiplicity and the average transverse pair

momentum. The measurement is performed with charged particles and the full available statistics in pp collisions, being also compared to previous one-dimensional results from CMS. The analysis is then extended to two- and three-dimensions for investigating the source lengths of homogeneity in different spatial directions. Furthermore, low  $p_T$  pions and kaons, which are identified from their energy loss in the silicon tracker, are used to further extend the measurements to pp, pPb and PbPb systems at the available energies. Radius fit parameters on the order of 1-5 fm are found, the largest values corresponding to very high multiplicity pPb interactions and for similar multiplicity PbPb collisions.

**WG4 QCD and Hadronic Final States / 171**

## **Measurement of the underlying event using track-jets with the CMS experiment**

**Corresponding Author:** paolo.gunnellini@cern.ch

A measurement of the underlying event activity in pp collisions is performed using events with a leading charged particle jet produced at central pseudorapidities and of transverse momentum in the range of 1 to 100 GeV. The underlying event activity is measured independently in the two halves of the transverse region with the maximum as well as minimum activities. The results obtained from pp collisions at center-of-mass energies of 0.9, 2.76 and 7 TeV are presented and compared to model predictions.

**WG4 QCD and Hadronic Final States / 172**

## **Measurement of Double Parton Scattering at LHC with the CMS experiment**

**Corresponding Author:** you-hao.chang@cern.ch

Double parton scattering is measured in different channels using the CMS experiment at the CERN LHC. Data from pp collisions collected at 7 and 8 TeV center-of-mass energy are used. Several final states are investigated to identify and measure the signature of double parton scattering in inelastic events. Parameters are extracted from the data that are suited in an optimal way to distinguish double parton scattering from various backgrounds. Multivariate analysis techniques are exploited to maximise the sensitivity.

**WG3:Electroweak Physics and Beyond the Standard Model / 174**

## **Search for $t\bar{t}$ resonances and dark matter at CMS**

**Corresponding Author:** paul.jonathan.turner@cern.ch

In many models of physics beyond the Standard Model the coupling of new physics to third generation quarks is enhanced. A search is presented for resonant top quark pair production. The full dataset recorded with the CMS detector in proton-proton collisions at a centre-of-mass energy of 8 TeV is used. The search is performed by measuring the invariant mass distribution of the top-quark pair and testing for deviations from the Standard Model prediction. We also present results from searches for Dark Matter produced in association with top quarks. Signatures investigated include those yielding top quark pairs or a single top quark plus missing transverse energy.

**WG3:Electroweak Physics and Beyond the Standard Model / 175****Searches for new heavy resonances and extra dimensions at CMS****Corresponding Author:** francesco.romeo@cern.ch

Final states with a pair of particles are sensitive to many models beyond the Standard Model (SM) and allow for a clean search for both new narrow resonances and broad deviations from SM predictions. The most recent results from searches with dijet, dileptons, and leptons plus missing transverse energy are presented using 20 fb<sup>-1</sup> of pp collision data collected by the CMS detector with sqrt(s) = 8 TeV at the LHC. No evidence is observed for physics beyond the SM and 95% confidence level limits are set on parameters from a number of theoretical models such as Z', W', Randall-Sundrum Gravitons, large extra dimension scenario, and contact interactions.

**WG1 Structure Functions and Parton Densities / 177****Timelike Compton Scattering off the nucleon: polarization observables and experimental perspectives for JLab-12 GeV****Author:** Marie Boër<sup>1</sup><sup>1</sup> *Institut de Physique Nucléaire d'Orsay*

Hard exclusive processes on the nucleon have been the subject of intense studies for the past 15 years. In the regime where the scattering amplitude is factorized into a hard and a soft part, such reactions provide access to Generalized Parton Distributions (GPDs). These quantities contain information about the longitudinal momentum and the transverse spatial distributions of quarks and gluons.

In this presentation, we will discuss our recent work on Timelike Compton Scattering (TCS), which corresponds to the reaction  $\gamma N \rightarrow \gamma^* N \rightarrow e^+e^- N$  and where the photon is scattered off a quark. This reaction also involves the Bethe-Heitler process, where the final state  $e^+e^-$  pair comes from the the initial photon. We derived the amplitudes of these processes and we calculated, at typical JLab-12 GeV energies, all the single and double beam and/or target polarization observables off the proton and off the neutron. We also studied the experimental feasibility of such measurements at JLab.

Reference :

M.Boër, M.Guidal and M.Vanderhaeghen, Single and double polarization observables in timelike Compton scattering off proton, arXiv:1501.00270 [hep-ph].

**WG2 Small-x, Diffraction and Vector Mesons / 178****The CMS-TOTEM Precision Proton Spectrometers CT-PPS****Author:** Michael Albrow<sup>1</sup><sup>1</sup> *Fermi National Accelerator Lab. (US)***Corresponding Author:** michael.albrow@cern.ch

The CMS-TOTEM Precision Proton Spectrometer, CT-PPS, is an approved project to add 3D silicon tracking and quartz Cherenkov timing detectors in Roman pots at  $z = \pm 210$  m from the CMS collision point to study final states  $p + X + p$ . The central state X can be a W-pair from

photon-photon interactions, a set of high-ET jets from gluon collisions, among others, with  $M(X)$  obtained directly as well as from the two outgoing protons. The project is designed to operate at high luminosity, with up to about 30 interactions per 25 ns bunch crossing, and to be fully operational for physics in 2016.

**WG4 QCD and Hadronic Final States / 180**

## Measurements of Drell-Yan transverse momentum and vector boson plus jets properties with the ATLAS detector

**Author:** Elizaveta Shabalina<sup>1</sup>

<sup>1</sup> *Georg-August-Universitaet Goettingen (DE)*

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The ATLAS Collaboration has performed precision measurements of the transverse momentum of the  $Z/\text{gammaboson}$  and the angular correlations of the Drell-Yan lepton pairs with the  $\phi$  observable, in different di-lepton invariant mass and rapidity regions. These measurements are sensitive to soft resummation effects and hard jet emissions for small and large momentum transfers, respectively, probing QCD in a unique way. Production of jets in association with a vector boson is an important process to study QCD in a multi-scale environment. The cross section, differential in several kinematics variables, have been measured with the ATLAS detector in 7 TeV proton-proton collisions up to high jet multiplicities and compared to state-of-the-art QCD calculations and Monte Carlo simulations.

**WG4 QCD and Hadronic Final States / 181**

## Measurement of the jet production properties with the ATLAS detector

**Author:** Elizaveta Shabalina<sup>1</sup>

<sup>1</sup> *Georg-August-Universitaet Goettingen (DE)*

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The measurements of the production cross sections of inclusive, di- and tri-jet events probe the dynamics of QCD and can constrain the parton proton structure. Double-differential cross sections are measured and compared to expectations based on next-to-leading order QCD calculations as well as to next-to-leading order Monte Carlo simulations. The study of di-jet systems with a veto on additional jets probe QCD radiation effects. These measurements constitute precision tests of QCD in a new energy regime.

**WG4 QCD and Hadronic Final States / 182**

## Measurement of photon production cross sections with the ATLAS detector

**Author:** Elizaveta Shabalina<sup>1</sup>

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Measurements of the inclusive photon production performed by the ATLAS collaboration are reported in different fiducial regions covering a wide acceptance. Comparisons to the data of next-to-leading order QCD calculations MCFM and JetPhox with different PDFs are presented. The theoretical uncertainties, including scale, strong coupling, and PDF uncertainties are evaluated. The cross sections for photons produced in association with jets are also measured by the ATLAS collaboration as functions of photon and jet kinematics and are compared to next-to-leading-order QCD calculations.

**WG4 QCD and Hadronic Final States / 183**

## Recent results on flow and correlations from the ATLAS experiment

**Author:** Elizaveta Shabalina<sup>1</sup>

<sup>1</sup> *Georg-August-Universitaet Goettingen (DE)*

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Measurements of soft particle production have provided valuable insight on properties of the evolution of the quark-gluon plasma in Pb+Pb collisions at the LHC. In particular, measurements of flow harmonics using the azimuthal angle distributions of low-pT particles directly test hydrodynamic model descriptions of its evolution. The large acceptance of the ATLAS detector enables the measurement of event-by-event flow and the correlations between different harmonics. Results will be presented from a variety of two-particle and multi-particle measurements in Pb+Pb and proton-Pb collisions.

**WG4 QCD and Hadronic Final States / 184**

## Jet measurements in p+Pb and Pb+Pb with the ATLAS Experiment at the LHC

**Author:** Elizaveta Shabalina<sup>1</sup>

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Recent results on electroweak probes in lead-lead and proton-lead collisions from the ATLAS Detector at the LHC  
 Abstract: Photons and weak bosons do not interact strongly with the dense and hot medium formed in the nuclei collisions, thus should be sensitive to the nuclear modification of parton distribution functions (nPDFs). In particular, proton-lead collisions provide an excellent opportunity to test nPDFs in a less dense environment than lead-lead. The ATLAS detector, optimized for searching new physics in proton-proton collisions, is especially well equipped to measure photons, Z and W bosons in the high occupancy environment produced in



heavy ion collisions. Using the full data samples of 2.76 TeV lead-lead and 5.02 TeV proton-lead collisions we will present recent results on the prompt photon, Z and W boson yields as a function of centrality, transverse momentum and rapidity, from the ATLAS experiment. The binary collision scaling of the yields will be discussed in detail.

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## Recent results on electroweak probes in lead-lead and proton-lead collisions from the ATLAS Detector at the LHC

**Author:** Elizaveta Shabalina<sup>1</sup>

<sup>1</sup> *Georg-August-Universitaet Goettingen (DE)*

**Corresponding Author:** elizaveta.shabalina@cern.ch

Photons and weak bosons do not interact strongly with the dense and hot medium formed in the nuclei collisions, thus should be sensitive to the nuclear modification of parton distribution functions (nPDFs). In particular, proton-lead collisions provide an excellent opportunity to test nPDFs in a less dense environment than lead-lead. The ATLAS detector, optimized for searching new physics in proton-proton collisions, is especially well equipped to measure photons, Z and W bosons in the high occupancy environment produced in heavy ion collisions. Using the full data samples of 2.76 TeV lead-lead and 5.02 TeV proton-lead collisions we will present recent results on the prompt photon, Z and W boson yields as a function of centrality, transverse momentum and rapidity, from the ATLAS experiment. The binary collision scaling of the yields will be discussed in detail.

WG3+WG4 Joint session / 186

## Higher-order corrections to the Higgs-boson pT distribution

**Authors:** Francis Petriello<sup>1</sup>; Jun Gao<sup>2</sup>; Radja Boughezal<sup>2</sup>

<sup>1</sup> *Northwestern University*

<sup>2</sup> *Argonne National Lab*

We present a study of the Higgs boson pT spectrum in hadronic collisions that incorporates all available perturbative information. A detailed investigation of the uncertainties affecting the prediction for the LHC is provided.

WG2 Small-x, Diffraction and Vector Mesons / 188

## Recent neutrino interaction cross section results from T2K

**Author:** Erez Reinherz-Aronis<sup>None</sup>

**Corresponding Author:** schol@phy.duke.edu

This talk will present recent results on neutrino interaction cross sections from the T2K experiment.

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## Measurement of the jet production cross sections with the ATLAS detector and their impact on PDF

**Author:** Elizaveta Shabalina<sup>1</sup>

<sup>1</sup> *Georg-August-Universitaet Goettingen (DE)*

**Corresponding Author:** elizaveta.shabalina@cern.ch

The measurements of the production cross sections of inclusive, di- and tri-jet events probe the dynamics of QCD and can constrain the parton proton structure. Double-differential cross sections are measured and compared to expectations based on next-to-leading order QCD calculations as well as to next-to-leading order Monte Carlo simulations. A QCD analysis of the data indicates constraining power for parton distribution functions of the proton.

WG4 QCD and Hadronic Final States / 190

## Measurements of particle production and Underlying Event properties with the ATLAS detector

**Author:** Elizaveta Shabalina<sup>1</sup>

<sup>1</sup> *Georg-August-Universitaet Goettingen (DE)*

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The measurement of production properties of mesons and baryons at  $\sqrt{s}=7$  TeV using pp collision data collected with the ATLAS experiment is presented and compared to predictions. Particle distributions sensitive to the underlying event in proton-proton collisions have also been measured with the ATLAS detector at the LHC at 7 TeV centre-of-mass energy. Various and complementary measurements are presented in the regions of each event azimuthally transverse to the hardest jet or the leading track or the Z-boson direction. When compared to the predictions of different Monte Carlo models, the data show sensitivity to modelling of the underlying event.

WG4 QCD and Hadronic Final States / 192

## Measurements of Bose-Einstein correlations with the ATLAS detector

**Author:** Elizaveta Shabalina<sup>1</sup>

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Bose-Einstein correlations provide a unique opportunity for detailed understanding of the space-time geometry of the hadronization region, for determining the size and shape of the source from which particles are emitted and for interpreting of quark confinement effects. Bose-Einstein correlation lead to an enhancement of the production of identical bosons close in phase space. The ATLAS collaboration has performed a measurement of Bose-Einstein correlations of the pairs of charged particles with transverse momentum greater than 100 MeV in p-p collisions at 900 GeV and 7 TeV. Bose-Einstein correlation parameters are investigated up to very high charged-particle multiplicities. The dependence of the Bose-Einstein correlation parameters on the average transverse momentum per pair and per particle is also investigated.

**WG3:Electroweak Physics and Beyond the Standard Model / 198**

## **Searches for new physics in high-mass resonances with the ATLAS detector at the LHC**

**Corresponding Author:** danhayden0@gmail.com

Many new physics scenarios beyond the Standard Model predict the presence of narrow or broad resonances decaying to a pair of fermions (light and heavy quarks, charged leptons and neutrinos) or bosons (gammagamma, WW, WZ, ZZ and HH). The high-mass resonant production of top-quark or vector boson pairs is also a good benchmark process for boosted top and massive boson tagging. This talk summarizes ATLAS searches for heavy resonances with LHC Run 1 data.

**WG3:Electroweak Physics and Beyond the Standard Model / 199**

## **Searches for heavy quarks and other signatures with the ATLAS detector at the LHC**

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Given that the Standard Model is very successful in describing the nature and no clue is found on the scale of new physics, signature-based search covering a wide range of final states and topologies has been more important nowadays. Searches for fermionic top/bottom quark partners, referred to as vector-like quarks, have been performed in various final states with leptons, jets and missing transverse momentum ( $p_T$ ). Searches in final states with a high  $p_T$  jet or boson recoiling against large missing energy are quite powerful for dark matter production. Long-lived, weakly-interacting particles predicted by various BSM models often lead to a signature with displaced decay vertices in ATLAS detector. This talk highlights ATLAS searches on vector-like quarks, dark matter and long-lived particles in LHC Run 1 data.

WG3:Electroweak Physics and Beyond the Standard Model / 202

## Latest Higgs results from ATLAS

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Run 1 measurements on the production and decay properties of the Higgs boson will be presented.

WG3:Electroweak Physics and Beyond the Standard Model / 203

## Beyond-the-Standard Model Higgs Physics using the ATLAS Experiment

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The discovery of a Higgs boson with a mass of about 125 GeV has prompted the question of whether or not this particle is part of a larger and more complex Higgs sector than that envisioned in the Standard Model. In this talk, the latest Run 1 results from the ATLAS Experiment on Beyond-the-Standard Model (BSM) Higgs searches are outlined. Searches for additional Higgs bosons are presented and interpreted in well-motivated BSM Higgs frameworks, including the two-Higgs-doublet Models and the Minimal and Next to Minimal Supersymmetric Standard Model.

WG3:Electroweak Physics and Beyond the Standard Model / 205

## Measurements of Multi-boson production, Trilinear and Quadratic Gauge Couplings with the ATLAS detector

**Corresponding Author:** karen.chen@cern.ch

The ATLAS collaboration has carried a set of measurements that provide stringent tests of the electroweak sector of Standard Model, specifically on di- and multi-boson production cross sections and on triple and quartic gauge-boson couplings. Such measurements include cross sections for  $WV$  ( $V=W$  or  $Z$ ) production in the leptonic or semileptonic channels, the production of a  $W$  or  $Z$  boson in association with photons, a  $Z$  boson in the vector-boson fusion channel and two same-charge  $W$  bosons in the vector-boson scattering channel.

These measurements are compared to (N)NLO predictions of the Standard Model and provide model-independent constraints on new physics, by setting limits on anomalous gauge-boson couplings. A global test of these Standard Model predictions can be made by studying of the common final state made up of a pair of an oppositely charged electron and muon. The simultaneous measurement of the cross-sections of the pair production of top quarks, tau-leptons via Drell-Yan, and  $WW$  bosons is performed in proton-proton collisions at  $\sqrt{s} = 7$  TeV. This analysis provides the underlying correlations in the predicted and measured cross-sections due to common proton parton distribution functions.

WG3:Electroweak Physics and Beyond the Standard Model / 207

## Precision measurements of Standard Model parameters with the ATLAS detector

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The ATLAS Collaboration is engaged in precision measurement of fundamental Standard Model parameters, e.g. the weak-mixing angle and the complete set of coefficients that describe the angular distributions of Drell-Yan production. A measurement of the forward-backward asymmetry for the neutral current Drell Yan process is presented and the results are then used to extract a measurement of the effective weak mixing angle. This measurement shows significant sensitivity to the uncertainties of the parton density functions of the proton. The angular distributions of the Drell-Yan lepton pairs around the Z-boson mass peak probe the underlying QCD dynamic of the Z-boson production mechanisms. We present a measurement of the complete set of angular coefficients describing these distributions using 8 TeV centre-of-mass energy. The measurement is compared with the theoretical predictions and shows discrimination power between different approaches of the QCD modeling.

**WG3:Electroweak Physics and Beyond the Standard Model / 211**

## Supersymmetry searches in ATLAS

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Despite the absence of experimental evidence, weak scale supersymmetry remains one of the best motivated and studied Standard Model extensions. This talk summarises recent ATLAS results for searches for supersymmetric (SUSY) particles. Weak and strong production in both R-Parity conserving and R-Parity violating SUSY scenarios are considered. The searches involved final states including jets, missing transverse momentum, light leptons, taus or photons, as well as long-lived particle signatures. Sensitivity projections for the data that will be collected in 2015 are also presented.

**WG1+WG5 Joint Session / 212**

## On the intrinsic heavy quark content of the nucleon and its impact on heavy new physics at the LHC

**Author:** Florian Lyonnet<sup>1</sup>

<sup>1</sup> LPSC

Heavy quark parton distribution functions (PDFs) play an important role in several Standard Model and New Physics processes. Most analyses rely on the assumption that the charm and bottom PDFs are generated perturbatively by gluon splitting and do not involve any non-perturbative degrees of freedom. On the other hand, non-perturbative, intrinsic heavy quark parton distributions have been predicted in the literature. We demonstrate that to a very good approximation the scale-evolution of the intrinsic heavy quark content of the nucleon is governed by non-singlet evolution equations.

This allows to analyze the intrinsic heavy quark distributions without having to resort to a full-fledged global analysis of parton distribution functions. We exploit this freedom to model intrinsic bottom distributions which are so far missing in the literature. We estimate the impact of the non-perturbative contribution to the charm and bottom-quark PDFs and on several important parton-parton luminosities at the LHC.

**WG5 Heavy Flavours / 214**

## **B-hadron production with the ATLAS experiment**

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We present the latest results from the ATLAS experiment on B-hadron production, including the  $B_c^+$  production cross-section measurement, observation of the  $B_c(2S)$  state, branching ratio measurement of  $B_c \rightarrow J/\psi D(\lambda)$  decay and extraction of fragmentation fractions  $f_s/f_d$  via reconstructed  $B_s \rightarrow J/\psi \Phi$  and  $B_d \rightarrow J/\psi K$  decays.

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## **Inclusive $D(^*)$ meson cross-section analysis**

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An updated measurement of the inclusive  $D(\lambda)$  meson  $x$ -section is presented. The  $x$ -section measurement has been performed in kinematic range  $3.5 < p_T(D(\lambda)) < 100$  GeV,  $|\eta(D(^*))| < 2.1$ , significantly extending the previous measurement. Comparisons with theoretical predictions (GM-VFNS, FONLL, POWHEG, MC@NLO) are discussed.

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## **Study of the $\Lambda_b$ decay properties with the ATLAS experiment**

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The ATLAS detector at the LHC is collecting - among others - a large statistics of  $\Lambda_b$  decays, allowing the study of production, decay modes and decay properties of this b-flavored hadron. This statistics is what allowed one of the most precise

measurements of the  $\Lambda_b$  lifetime. We will review ATLAS' latest results on the decay properties of this baryon, including new decay modes and measurement of the parity violating asymmetry parameter  $\alpha_b$  in  $\Lambda_b \rightarrow \Lambda J/\psi$  obtained from the study of angular correlations in the  $p \pi^+ \pi^-$  final state. The measurement is compared to predictions based on perturbative QCD and heavy quarks effective theory.

**WG5 Heavy Flavours / 217**

## **ATLAS search for $X_b \rightarrow \pi^+ \pi^- Y(1S)$ counterpart to the $X(3872)$**

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The existence of the  $X(3872)$  suggests the presence of its bottomonium counterpart  $X_b$ . Search for  $X_b$  with the ATLAS experiment in several final states, including  $Upsilon \pi \pi$ , is presented.

**WG5 Heavy Flavours / 218**

## **Top quark pair production cross section using the ATLAS detector at the LHC**

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Measurements of the inclusive top quark pair production cross sections in proton-proton collisions with the ATLAS detector at the Large Hadron Collider are presented. The measurements are performed requiring one or two electrons or muons in the final state. Various experimental techniques are compared. The most precise result requires opposite sign electrons and muons and uses the full data-set at a centre-of-mass energy of 8 TeV. In addition, differential measurements of the top transverse momentum and kinematic properties of the top-anti-top pair are discussed. These measurements, including results using boosted tops, probe our understanding of top pair production in the TeV regime. The results, unfolded to particle and parton level, are compared to recent Monte Carlo generators implementing LO and NLO matrix elements matched with parton showers and NLO QCD calculations. The data show some sensitivity to parton density functions.

**WG5 Heavy Flavours / 219**

## Production of top pair events with additional radiation using the ATLAS detector at the LHC

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The large centre-of-mass energy available at the proton-proton collider LHC allows for the copious production of top quark pairs in association with other final state particles at high transverse momentum. The ATLAS experiment has measured several final state observables that are sensitive to additional radiation in top anti-top quark final states. Results on the top production in association with W and Z bosons are presented along with measurements of the cross section for production with an associated isolated photon. Analyses probing the top pair production with additional QCD radiation include the multiplicity of jets for various transverse momentum thresholds or the probability to emit jets above a given threshold in a fixed rapidity region. These measurements are compared to modern Monte Carlo generators based on NLO QCD matrix element or LO multi-leg matrix elements. The data are able to constrain the uncertainty on the modelling of the top pair production mechanism. We also discuss the production of top quark pairs in association with additional b-jets.

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## Top quark pair properties - spin correlations, top quark pair asymmetry and complex final states using the ATLAS detector at the LHC

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<sup>1</sup> *Louisiana Tech University (US)*

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The top quark pair charge asymmetry is an asymmetry predicted to occur beyond leading-order QCD in the Standard Model, and may be significantly enhanced by the presence of new physics. The  $t\bar{t}$  production charge asymmetry is measured inclusively and differentially using the 7 and 8 TeV ATLAS datasets. Making use of the large number of top quark pairs collected, we also present measurements of the spin correlation between top and anti-top quarks using several variables and discuss their sensitivity to new physics. A search for flavour changing neutral current processes in top quark decays is also presented.

WG3+WG5 Joint Session / 221

## Measurements of the top quark mass using the ATLAS and CMS detectors at the LHC

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The latest measurements of the top quark mass using the ATLAS experiment are presented. A measurement based on a multi-dimensional template fit that can constrain the uncertainties on the energy measurements of jets is presented and combined with a measurement using dilepton events. In addition, novel measurements aiming to measure the mass in a well-defined scheme are presented. These measurements use precision theoretical QCD calculations for both inclusive  $t\bar{t}$  production and  $t\bar{t}$  production with an additional jet to extract the top quark mass in the pole-mass scheme.

Measurements of the top quark mass are presented, obtained from CMS data collected in proton-proton collisions at the LHC at centre-of-mass energies of 7 TeV and 8 TeV. The mass of the top quark is measured using several methods and channels, including the reconstructed invariant mass distribution of the top quark, an analysis of endpoint spectra as well as measurements from shapes of top quark decay distributions. The dependence of the mass measurement on the kinematic phase space is investigated. The results of the various channels are combined and compared to the world average. The top mass and also  $\alpha_s$  are extracted from the top pair cross section measured at CMS.

**WG3+WG5 Joint Session / 222**

## Single Top quark production cross section measurements using the ATLAS and CMS detectors at the LHC

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Measurements of single top-quark production in proton-proton collisions at 7 and 8 TeV are presented. In the leading order process, a W boson is exchanged in the t-channel. The single top-quark and anti-top total production cross sections, their ratio, as well as a measurement of the inclusive production cross section is presented. In addition, a measurement of the production cross section of a single top quark in association with a W boson is presented. All measurements are compared to state-of-the-art theoretical calculations and the CKM matrix element  $|V_{tb}|$  is determined. In addition, the s-channel production is explored and limits on exotic production in single top quark processes are discussed. This includes the search for flavor-changing neutral currents and the search for additional W' bosons or a search for monotops.

Measurements of single top quark production are presented, performed using CMS data collected in 2011 and 2012 at centre-of-mass energies of 7 and 8 TeV. The cross sections for the electroweak production of single top quarks in the t-channel and in association with W-bosons is measured and the results are used to place constraints on the CKM matrix element  $V_{tb}$ . In the t-channel the ratio of top and anti-top production cross sections is determined and compared with predictions from different parton density distribution functions. Measurements of top quark properties in single top quark production are also presented. The results include the W-helicity in top quark decay and the searches for s-channel production and for anomalous couplings.

**WG7 Future experiments / 223****Physics prospects with the upgraded ATLAS detector****Author:** Flera Rizatdinova<sup>1</sup><sup>1</sup> *Oklahoma SU***Corresponding Author:** flera.rizatdinova@cern.ch

Run-I at the LHC has been very successful, including the discovery of a new particle with a mass of about 125 GeV and with properties compatible with those of the Standard Model Higgs boson within uncertainties. Precise measurements of the properties of this boson, and the discovery of new physics beyond the Standard Model, are primary goals of future running at the LHC. The physics prospects based on 300/fb and 3000/fb protonproton collision data to be collected at 14 TeV are presented. The ultimate precision attainable on measurements of the couplings of the 125 GeV particle to elementary fermions and bosons is discussed, as well as perspectives on the searches for partners associated with this new object, predicted by several extensions of the standard theory. Supersymmetry is one of the best motivated and well-studied extensions of the Standard Model. The current searches at the LHC have yielded sensitivity to TeV scale gluinos and 1st and 2nd generation squarks, as well as to 3rd generation squarks and electro-weakinos in the hundreds of GeV mass range. Benchmark studies are presented to show how the discovery potential can be extended for inclusive strong production of squarks and gluinos, direct production of 3rd generation squarks and weak production of electro-weakinos. A considerable fraction of the parameter space for a wide variety of other models has been probed with the 8 TeV data. The prospects of searches for new heavy bosons and dark matter candidates at 14 TeV are explored here. For all these studies, a parameterised simulation of the Upgraded ATLAS detector is used, taking into account the expected pileup conditions.

**WG3+WG7 Joint Session / 224****Precision test of fundamental interactions with the ELBNF Near Detector****Author:** Vittorio Paolone<sup>1</sup>**Co-author:** Roberto Petti<sup>2</sup><sup>1</sup> *University of Pittsburgh*<sup>2</sup> *University of South Carolina (US)***Corresponding Author:** roberto.petti@cern.ch

The reference design of the near detector for the LBNE/F experiment is a high-resolution, low density (about 0.1 g/cm<sup>3</sup>) Fine-Grained Tracker (FGT), which, in conjunction with the high intensity and broad energy range of the LBNE/F beam, will allow precise tests of fundamental interactions resulting in a better understanding of the structure of matter. Overall, FGT is expected to collect about 10<sup>8</sup> inclusive neutrino charged current (CC) interactions with a bubble-chamber quality reconstruction of secondary charged and neutral particles. The rich physics program includes precision electroweak measurements (Weak Mixing Angle - WMA)

using different independent channels from NC/CC DIS to neutrino-electron NC elastic scattering, measurement of the Adler sum rule and precision tests of isospin symmetry, measurements of nucleon and nuclear structure functions, searches for New Physics, etc. We will discuss the physics potential of FGT and present a few precision measurements.

#### WG1 Structure Functions and Parton Densities / 225

### Cross-section and structure function measurements with the ELBNF Near Detector

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**Co-author:** Roberto Petti<sup>2</sup>

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The high resolution near detector for the LBNE/F experiment, in conjunction with the high intensity and broad energy range of the LBNE/F beam, will allow to collect about  $10^8$  inclusive neutrino charged current (CC)

interactions with a bubble-chamber quality reconstruction. Precision measurements of cross-sections for several exclusive processes and of structure functions ( $F_T$ ,  $F_2$ ,  $F_3$ ,  $R$ ) of nucleon and nuclei are planned.

One key feature of the experimental program is the availability of several nuclear targets including polypropylene ( $C_3H_6$ )<sub>n</sub>, C, Ar, Ca, Fe, H<sub>2</sub>O, D<sub>2</sub>O, etc. which will allow model-independent measurements

of nuclear effects in neutrino interactions. From a statistical subtraction of the C target from the polypropylene ( $C_3H_6$ )<sub>n</sub> one we will obtain interactions on free proton. The use of both neutrino and anti-neutrino beams on such a free proton target will allow a direct measurement of the free neutron structure functions, as well as the determination of the d/u ratio at large values of Bjorken  $x$ .

#### WG7 Future experiments / 226

### Measurements of The Neutrino Flux Using Fine-Grained Tracker

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The reference design of the near detector for the LBNE/F experiment is a high-resolution Fine-Grained Tracker (FGT)

capable of precisely measuring all four species of neutrinos:  $\nu_\mu$ ,  $\nu_e$ ,  $\bar{\nu}_\mu$  and  $\bar{\nu}_e$ . The goals of the FGT is to

constrain the systematic errors, below the corresponding statistical error in the far detector, for all oscillation studies; and to conduct a panoply of precision measurements and searches in neutrino physics.

We present sensitivity studies of measurements –critical to constraining the systematics in oscillation searches –

of the absolute and relative neutrino flux using the various techniques: 1) neutrino electron NC (CC) scattering, 2)  $\bar{\nu}\mu$  proton QE scattering, 3) Coherent  $\rho$  production for absolute flux and 4) Low- $v$  method for relative flux. Historically, the limited knowledge of the (anti)neutrino fluxes has been the dominant systematic uncertainty for past neutrino scattering experiments. The precision in the determination of the absolute and relative fluxes achieved in FGT will allow for the first time to fully exploit the potential of the (anti)neutrino probe.

#### WG1 Structure Functions and Parton Densities / 227

### EMC effect: Past, Present, and Future

**Author:** Nadia Fomin<sup>1</sup>

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Since the discovery of the EMC effect over 30 years ago, it's been of great theoretical interest and studied in several experimental measurements. No unified picture arose to explain the underlying cause of per nucleon structure function modification in nuclei. Precise measurements on light nuclei from JLab's 6 GeV era revitalized this research by showing that traditional A or density dependent models of this nuclear modification do not work. The measurements will be reviewed, discussed and preliminary data on heavy targets from JLab's E03-103 will be presented.

#### WG3+WG4 Joint session / 228

### N3LO Higgs boson production

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We present the soft-virtual corrections to Higgs boson production in gluon fusion for infinite top quark mass at next-to-next-to-next-to-leading order in QCD. In addition, we show analogous soft-virtual terms for both Drell-Yan lepton production in QCD and scalar pair production in  $N = 4$  super Yang-Mills theory. The result for Drell-Yan lepton production is derived from the result for Higgs boson production using Casimir scaling arguments together with well-known results available in the literature. For scalar pair production in the  $N = 4$  model, we show by explicit calculation that the result is equal to the part of the Higgs boson soft-virtual term which is of maximal transcendentality weight.

#### WG7 Future experiments / 230

### A dedicated eRHIC Detector and Interaction Region design

**Author:** Alexander Kiselev<sup>1</sup>

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Construction of an Electron-Ion Collider with luminosities exceeding  $10^{33} \text{ cm}^{-1} \text{ s}^{-1}$  is becoming a project of highest priority for the US

Nuclear Physics community.

The main physics topics to be explored at this new facility are (i) the polarized sea quark and gluon distributions

in the nucleon, (ii) QCD dynamics of the low-x, high density gluon regime,

(iii) hadronization and energy loss in the nuclear medium [1].

One of the considered construction options is the addition

of a high-energy polarized electron beam to the existing RHIC hadron

machine, converting it into an Electron-Ion Collider (eRHIC) [2].

A dedicated eRHIC detector, designed to efficiently register and identify deep inelastic electron scattering (DIS) processes in a wide range of

center-of-mass energies available with the new collider is one of the key

elements of such an upgrade.

The progress on the detector and interaction

region design work will be shown, and the simulation results presented.

[1] A. Accardi et al., "Electron Ion Collider: The Next QCD Frontier - Understanding the glue that binds us all" (EIC White Paper), arXiv:1212.1701v3 (2014).

[2] E.C. Aschenauer et al., "eRHIC design study (An Electron-Ion Collider at BNL)", arXiv:1409.1633 (2014).

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## WG1 Highlights: Structure Functions and Parton Densities

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## WG2 Highlights: Small-x, Diffraction and Vector Mesons

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## WG3 Highlights: Electroweak Physics and Beyond the Standard Model

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## WG4 Highlights: QCD and Hadronic Final States

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## **WG5 Highlights: Heavy Flavors**

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## **WG6 Highlights: Spin Physics**

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## **WG7 Highlights: Future experiments**

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## **Particle physics from the Asian perspective**

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## **DIS outlook**

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## Summary of IAC meeting

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## WG1 Highlights: Structure Functions and Parton Densities

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## WG2 Highlights: Small-x, Diffraction and Vector Mesons

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## WG3 Highlights: Electroweak Physics and Beyond the Standard Model

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## Closing Remarks

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WG6 Spin Physics / 248

## Measurement of transverse single-spin asymmetry and cross-section ratios of kinematically fully reconstructed weak bosons in p+p collisions at $\sqrt{s} = 500 - 510$ GeV at RHIC

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We present the status and preliminary results on the analysis of kinematically fully reconstructed weak bosons at the STAR experiment.

The transverse single spin asymmetry ( $A_N$ ) has been measured in transversely polarized proton-proton collisions at  $\sqrt{s} = 500$  GeV, with a recorded integrated luminosity of  $25 \text{ pb}^{-1}$ .

The measured observable is sensitive to the non-universality of the Sivers function, a fundamental prediction from the gauge invariance of QCD, and can provide a direct verification of transverse momentum dependent (TMD) distributions factorization. Furthermore, it provides an ideal tool to study the spin-flavor structure of valence and sea quarks inside the proton and to test the evolution of parton distributions.

The  $W^+/W^-$  cross section ratio has been measured in unpolarized proton-proton collisions at  $\sqrt{s} = 500 - 510$  GeV, with a recorded integrated luminosity of  $110 \text{ pb}^{-1}$ . The observable is sensitive to the flavor asymmetry in sea anti-quarks for Bjorken- $x > 0.1$  accessible at RHIC, providing an independent constraint on the large flavor asymmetry observed in Drell-Yan experiments, without the assumption of charge symmetry required in fitting the Drell-Yan data.

In addition, the future opportunities for a precise measurement of  $A_N$  in weak boson production at STAR will be discussed as well as other observables sensitive to the non universality of the Sivers function, i.e. direct photon  $A_N$ .

**WG3:Electroweak Physics and Beyond the Standard Model / 249**

## **NLO+NLL limits on $W'$ and $Z'$ gauge boson masses in general extensions of the Standard Model**

**Author:** Florian Lyonnet<sup>1</sup>

<sup>1</sup> LPSC

QCD resummation predictions for the production of  $W'$  and  $Z'$  heavy gauge bosons decaying leptonically will be presented. The results of our resummation code at next-to-leading order and next-to-leading logarithmic accuracy will be compared to Monte Carlo predictions obtained with PYTHIA at leading order supplemented with parton showers and FEWZ at NLO and next-to-next-to-leading order for the  $p_T$ -differential and total cross sections in the Sequential Standard Model and general  $SU(2) \times SU(2) \times U(1)$  models. Finally, new limits at NLO+NLL on  $W'$  and  $Z'$  boson masses obtained by reinterpreting recent ATLAS and CMS results in general extensions of the Standard Model will be presented.

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## **QCD in the era of the Higgs**

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## **PDFs from protons to nuclei**

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## **HERA collider results**

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## **Small-x, Diffraction and Vector Mesons**

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## **BSM physics in the LHC13 era**

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## **News from the LHC**

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## **QCD precision predictions and showering programs**

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## **Heavy Flavours**

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## **QCD at the Tevatron**

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## Spin Physics and transverse structure

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## Recent results in higher-order QCD

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WG2 Small-x, Diffraction and Vector Mesons / 261

## Measurement of the total cross section in pp collisions at $\sqrt{s}=7$ TeV with the ALFA sub-detector of ATLAS

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The total pp cross section is a fundamental parameter of the strong interaction which cannot be calculated in QCD but still can be measured using the optical theorem, which states that the total cross section can be obtained from the extrapolation to  $t=0$  of the differential elastic cross section measured at small four-momentum transfer  $t$ .

The ATLAS Collaboration has collected 80 mb<sup>-1</sup> of elastic data in a dedicated run with high beta\* optics at 7 TeV centre-of-mass energy with the ALFA Roman Pot detector in order to perform this measurement. From the extrapolation of the differential elastic cross section to  $t=0$  using the optical theorem the total cross section is extracted with the luminosity-dependent method. In addition the nuclear slope of the elastic  $t$ -spectrum, the total elastic and inelastic cross sections are determined.

WG7 Future experiments / 262

## Neutrino-Nucleus Deep Inelastic Scattering in MINERvA in the NuMI Medium Energy Beam

Author: Anne Norrick<sup>1</sup>

<sup>1</sup> The College of William and Mary

Neutrino Nucleon Deep Inelastic Scattering (DIS) events in MINERvA provide a probe into the structure of nucleons within the nucleus that is different, due to the axial-vector component, than charged-lepton nucleon interactions. The MINERvA experiment is stationed in the Neutrinos from the Main Injector (NuMI) beam line at Fermi National Accelerator Laboratory. With the recent increase in average neutrino event energy to 9 GeV and the greatly increased intensity of the NuMI beam line, projected sensitivities for nuclear structure function analyses using MINERvA's suite of nuclear targets (C, CH, Fe and Pb) will be greatly increased. The projected reach and impact of these measurements will be discussed.

Plenary / 263

## Welcome

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WG3:Electroweak Physics and Beyond the Standard Model / 264

## On the annihilation rate of WIMPs

Author: Varun Vaidya<sup>1</sup><sup>1</sup> *Carnegie Mellon University*

We systematically compute the annihilation rate for neutral winos into the final state  $\gamma + X$ , including all leading radiative corrections. This includes both the Sommerfeld enhancement (in the decoupling limit for the Higgsino) and the resummation of the leading electroweak double logarithms. Adopting an analysis of the HESS experiment, we place constraints on the mass as a function of the wino fraction of the dark matter and the shape of the dark matter profile. We also determine how much coring is needed in the dark matter halo to make the wino a viable candidate as a function of its mass. Additionally, as part of our effective field theory formalism, we show that in the pure-Standard Model sector of our theory, emissions of soft Higgses are power-suppressed and that collinear Higgs emission does not contribute to leading double logs.

WG1 Structure Functions and Parton Densities / 265

## Combination of PDF uncertainties for LHC observables

Author: Pavel Nadolsky<sup>1</sup><sup>1</sup> *Southern Methodist University*

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I review two methods for combination of PDF+QCD coupling uncertainties for LHC observables, based on meta-parametrizations of PDFs and compressed Monte Carlo replicas. The methods estimate combined PDF uncertainties using input PDF ensembles from several groups. They offer alternatives to the current PDF4LHC prescription for the combination of PDF uncertainties, and combine the PDFs at the level of their functional forms, rather than at the level of final physical predictions. Strengths of both methods are compared, and prospects for their implementation in future analyses are discussed.

WG5 Heavy Flavours / 266

## NLO Monte Carlo predictions for heavy-quark production at ALICE

Author: Karol Kovarik<sup>None</sup>

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We present a comparison of NLO QCD predictions for heavy-quark production at the LHC. We compare theoretical predictions obtained with POWHEG to different predictions where fixed-order calculations are extended with next-to-leading logarithms and to predictions using the GM-VFNS. We focus on the productions of neutral and charged D mesons in proton-proton collisions at ALICE in an attempt to better understand the theory uncertainty for the baseline processes before studying the heavy-quark suppression in heavy-ion collisions.

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## The Gottfried Sum Rule Revisited

**Author:** Cynthia Keppel<sup>1</sup>

**Co-authors:** Gabriel Niculescu<sup>2</sup>; Ioana Niculescu<sup>2</sup>; Simona Malace

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Significant progress has recently been made, both experimentally and theoretically, in extracting the neutron structure function from deuterium data. Of particular note is the Jefferson Lab “BONUS” experiment, where a novel tagged proton spectator approach was employed to isolate the neutron target in electron-deuteron scattering. The BONUS data, combined with a wealth of precision deuterium data from Jefferson Lab, SLAC, and NMC, the latter now all with state-of-the-art nuclear corrections applied, has been used to re-evaluate the Gottfried Sum rule integrand  $F_2n-F_2p$ . Results of this analysis will be presented, and compared with the well-known results from NMC which lacked precision neutron extraction.

**WG7 Future experiments / 268**

## The Status and Prospects of the LHeC and FCC-he Developments

**Author:** Nestor Armesto Perez<sup>1</sup>

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An intense electron beam, when combined with the LHC (LHeC) or, in the further future, the FCC hadron beams (FCC-he), can lead to a unique, energy frontier DIS collider at CERN. This talk presents a summary of recent studies, including those about the design of the SCRF cavities and an initial Energy Recovery Linac Test Facility.

**WG3+WG7 Joint Session / 269**

## Precision Higgs Measurements at the LHeC

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An intense electron beam, when combined with the LHC (LHeC) or, in the further future, the FCC hadron beams (FCC-he), can lead to a unique, energy frontier DIS collider at CERN. In this talk, simulations are shown and prospects are outlined for precision measurements of the Higgs boson properties in high luminosity CC scattering at the LHeC.

**WG7 Future experiments / 271**

## Parton Distributions, QCD Measurements, and BSM Prospects with the LHeC

**Author:** Nestor Armesto Perez<sup>1</sup>

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An intense electron beam, when combined with the LHC (LHeC) or, in the further future, the FCC hadron beams (FCC-he), can lead to a unique, energy frontier DIS collider at CERN. New simulations are shown on the potential of measuring the full set of parton distributions in the proton and of their effect on the Higgs cross section in pp collisions.

**WG7 Future experiments / 272**

## Top quark physics in ep collisions

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An intense electron beam, when combined with the LHC (LHeC) or, in the further future, the FCC hadron beams (FCC-he), can lead to a unique, energy frontier DIS collider at CERN. Recent measurements at the LHC and the Tevatron have lead to a very precise determination of  $m_{\text{top}}$  with, however, sizeable theoretical and phenomenological uncertainties inherent to hadron-hadron scattering. High precision top physics can be performed in ep scattering at the LHeC which is analysed in this presentation. Besides, it is also discussed how polarised ep scattering (at low and very high energies) can lead to very interesting prospects for measuring the scale dependence of the weak mixing angle at very small scales  $O(1)\text{GeV}$  and much beyond the Z pole where LEP/SLC provided two measurements of  $\sin^2 \theta(M_Z)$ .

**WG7 Future experiments / 273**

## Electron-Ion Physics with the LHeC

**Author:** Nestor Armesto Perez<sup>1</sup>

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An intense electron beam, when combined with the LHC (LHeC) or, in the further future, the FCC hadron beams (FCC-he), can lead to a unique, energy frontier DIS collider at CERN. New results are shown of evaluations of the potential of eA physics at the energy frontier, including, for the first time, a determination of nuclear parton distributions based on only (simulated) eA data input.

**WG7 Future experiments / 274**

## A detector for energy-frontier ep scattering

**Author:** Peter Kostka<sup>1</sup>

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An intense electron beam, when combined with the LHC (LHeC) or, in the further future, the FCC hadron beams (FCC-he), can lead to a unique, energy frontier DIS collider at CERN. Updates of the LHeC ep/A detector configuration are presented with a view to optimising Higgs physics and to extend the concept to the FCC-he.

**WG3:Electroweak Physics and Beyond the Standard Model / 275**

## Search for right-handed neutrinos at CMS

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The origin of neutrino mass has been a longstanding question in high energy particle physics. One possible solution arises through the seesaw mechanism if neutrinos have a Majorana mass term. The most conclusive proof of Majorana neutrinos may be their detection from direct production of heavy right-handed neutrinos at the LHC. Limits on the existence of heavy right-handed neutrinos are placed through two searches performed by the Compact Muon Solenoid Collaboration. Each search targets the final state containing two same-flavor leptons and two jets. While the first search targets the production of right-handed neutrinos through mixing with the Standard Model W boson, the second search focuses on right-handed neutrinos produced through a heavy right-handed W boson consistent with the left-right symmetric extension of the Standard Model.

**WG7 Future experiments / 276**

## Medium Energy Electron Ion Collider at Jefferson Lab

**Author:** He Zhang<sup>1</sup>

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

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At Jefferson Lab, the conceptual design of a next generation facility, the medium energy electron ion collider (MEIC), to reach the frontier in Quantum Chromodynamics has been carried on for years. The MEIC will provide an electron beam with energy up to 10 GeV, a proton beam with energy up to 100 GeV, and heavy ion beams with corresponding energy per nucleon with the same magnetic

rigidity. The center-of-mass energy goes up to 70 GeV. Both the proton beam and the light-ion beams have high polarization above 70%. Two detectors, a primary one with full acceptance and a high-luminosity one with less demanding specification, are proposed. With the implementation of the traditional electron cooling in both the ion booster ring and the ion collider ring, particularly ultrahigh luminosity close to  $1034 \text{ cm}^{-2}\text{s}^{-1}$  per detector with large acceptance can be achieved. We will present the recent progress in MEIC design.

**WG4+WG5 Joint Session / 277**

## Measurement of Vector boson + Heavy flavor jet production rates by D0

**Author:** Ashish Kumar<sup>1</sup>

<sup>1</sup> *State University of New York (US)*

We present recent results on heavy flavor jet production in association with weak vector bosons using proton-antiproton collision data collected with the D0 detector at center of mass energy  $\sqrt{s}=1.96 \text{ TeV}$ . We discuss in particular the measurements of W+b/c-jet production cross-sections and the ratio of cross-sections,  $\sigma(Z+2b\text{-jet})/\sigma(Z+2\text{jets})$ . Study of these processes provide tests of perturbative QCD predictions and non-perturbative effects. These processes are also important backgrounds to many precision SM measurements as well as to searches for new physics.

**WG3+WG5 Joint Session / 278**

## Measurements of the top quark mass at D0

**Author:** Huanzhao Liu<sup>1</sup>

<sup>1</sup> *SMU*

We present measurements of the mass of the top quark using the full D0 Run II data set corresponding to an integrated luminosity of  $9.7 \text{ fb}^{-1}$ . Results in the dilepton and lepton+jets decay channel of the top quark will be discussed. In the dilepton decay channel we employ the neutrino weighting technique based on the expected neutrino rapidity distribution, whereas in the lepton+jets channel we use the matrix element method to extract a measurement of the top quark mass. The measured values will be reported and compared to other recent mass measurements.

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## Vector Boson production with Heavy Ions at the LHC

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

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High Energy proton-proton collisions at the LHC are capable of producing many electroweak bosons ( $W/Z$ ) at high rapidity. Measurements of properties of these particles are essential standard candles used to calibrate detectors such as ATLAS and CMS. The collision of heavy nuclei can show significant modifications to the distribution of these bosons. We will present an analysis of electroweak boson production in lead-lead and proton-lead collisions at the LHC using the nCTEQ nuclear Parton Distribution Functions (nPDFs). The cross-sections are calculated at NLO with FEWZ at 2.76 and 5.02 TeV respectively. Comparison to other popular nPDF distributions will also be presented.

**WG2 Small-x, Diffraction and Vector Mesons / 280**

## **Classical Gluon Production Amplitude for Nucleus–Nucleus Collisions: First Saturation Correction in the Projectile**

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The classical single-gluon production amplitude in nucleus-nucleus collisions including the first saturation correction in one of the nuclei (the projectile) while keeping multiple-rescattering (saturation) corrections to all orders in the other nucleus (the target) is presented. We expand one of the two nuclei up to two Wilson lines (i.e only two nucleons interact in the projectile nucleus): the single-gluon production amplitude we calculate is order- $g^3$  and is leading-order in the atomic number of the projectile, while resumming all order-one saturation corrections in the target nucleus. Our result is the first step towards obtaining an analytic expression for the first projectile saturation correction to the gluon production cross section in nucleus–nucleus collisions.

**WG4 QCD and Hadronic Final States / 281**

## **Jet-veto resummation for WW production**

**Author:** Prerit Jaiswal<sup>1</sup>

**Co-author:** Takemichi Okui<sup>2</sup>

<sup>1</sup> *Syracuse University*

<sup>2</sup> *Florida State University*

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The WW production cross-section measured at the LHC has been consistently exhibiting a mild excess beyond the SM prediction leading to speculations that new physics could be hiding in these measurements. In this talk, I discuss a possible explanation of the excess in terms of large logarithms that arise from a jet-veto condition that is imposed in the experimental analyses to reduce backgrounds. Resummation of these logarithms is performed analytically by employing soft collinear effective theory, and the results are compared with the Monte Carlo predictions. Resummation of terms associated with complex values of scales is also considered providing a more reliable method of estimating scale uncertainties.

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## **Impact of global direct photon data on the gluon distribution function**

**Author:** nobuo sato<sup>1</sup>



**Co-author:** Joseph Owens <sup>2</sup>

<sup>1</sup> *jlab*

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In this talk we will discuss the phenomenology of direct photon production using theoretical predictions at *\emph{next-to-leading order}* with threshold resummation up to *\emph{next-to-leading-logarithmic}* accuracy. By analyzing the global data sets of direct photons, we found good agreement between the theory and the data for a wide range of energies ( $\sqrt{s} = 23$  GeV up to 7 TeV) if we exclude the data from E706 experiment. We have studied the potential impact of direct photon data on parton distribution functions using a Bayesian reweighting approach. A reduction of 10% around  $0.3 < x < 0.6$  is observed in the uncertainty of the gluon distribution.

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## Search for the Zb(10610) and the Zb(10650) in ppbar collisions at $\sqrt{s}=1.96$ TeV

**Author:** Braden Keim Abbott<sup>1</sup>

<sup>1</sup> *University of Oklahoma (US)*

We present a search for the Zb(10610) and the Zb(10650) using the decay  $Z_b \rightarrow Y(nS)\pi^\pm$  where  $Y(nS) \rightarrow \mu\mu$  in  $10.4 \text{ fb}^{-1}$  of ppbar collisions at  $\sqrt{s}=1.96$  TeV collected by the D0 experiment during Run II of the Tevatron collider. Sensitivity to the production of Zb is demonstrated and the results of the search will be presented for the first time.

**WG7 Future experiments / 284**

## A High Energy e-p/A Collider Based on CepC-SppC

**Author:** Yuhong Zhang<sup>1</sup>

<sup>1</sup> *Thomas Jefferson National Accelerator Facility*

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The proposal of Construction of CepC and SppC, the next generation energy frontier e+e- and pp circular colliders, in a common accelerator complex provides an opportunity to realize collisions of protons or ions with electrons or positrons in an ultra high center-of-mass energy range up to 4.2 TeV. This paper presents a preliminary design study of this e-p/A collider based on the CepC-SppC facility. The design parameters for different operational scenarios and anticipated luminosities (up to middle of  $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ ) will be given. We also discuss two staging approaches to realize this collider with a low cost and at an earlier time

**WG2 Small-x, Diffraction and Vector Mesons / 286**

## Improved effective TMD factorization for forward dijet production in p-A collisions

**Authors:** Andreas van Hameren<sup>1</sup>; Cyrille Marquet<sup>2</sup>; Elena Petreska<sup>3</sup>; Krzysztof Kutak<sup>4</sup>; Piotr Kotko<sup>None</sup>; Sebastian Piotr Sapeta<sup>5</sup>

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We study forward dijet production in dilute-dense hadronic collisions. By considering the appropriate limits, we show that both the transverse-momentum-dependent (TMD) and the high-energy factorization formulas can be derived from the Color Glass Condensate framework. Respectively, this happens when the transverse momentum imbalance of the dijet system,  $k_t$ , is of the order of either the saturation scale, or the hard jet momenta, the former being always much smaller than the latter. We propose a new formula for forward dijets that encompasses both situations and is therefore applicable regardless of the magnitude of  $k_t$ . That involves generalizing the TMD factorization formula for dijet production to the case where the incoming small- $x$  gluon is off-shell. The derivation is performed in two independent ways, using either Feynman diagram techniques, or color-ordered amplitudes.

WG7 Future experiments / 287

## The Halls B and C semi-inclusive deep inelastic scattering program towards the transverse momentum dependence of valence quarks

**Author:** Rolf Ent<sup>1</sup>

**Co-author:** Harut Avakian<sup>1</sup>

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Inclusive and semi-inclusive deep inelastic scattering (DIS and SIDIS) are important tools for understanding the structure of nucleons and nuclei. Spin asymmetries in polarized SIDIS are directly related to transverse momentum dependent parton distributions (TMDs) and fragmentation functions. The usual collinear parton distribution functions depend on the fraction of hadron momentum carried by the parton,  $x$ , and the space-time resolution scale,  $Q^2$ . The TMDs, which depend also on the intrinsic transverse momentum of the parton,  $k_T$ , provide a three-dimensional partonic picture of the nucleon in momentum space. These TMDs have not yet been studied in detail. The 12 GeV era at JLab can move this to a new level of sophistication, thanks to the extraordinary statistical accuracy achievable and the extended kinematic reach provided by the 11 GeV beam. This calls for a multi-pronged approach with multi-dimensional data, for all combinations of beam and target polarization, and different hadrons. Hall B with its large-acceptance CLAS12 spectrometer will likely be the workhorse of SIDIS physics to provide multi-dimensional cross sections, azimuthal distributions and single- and double-spin asymmetries, using both unpolarized and polarized proton and deuteron targets, and unpolarized nuclear targets. The much-anticipated addition of a RICH detector to the CLAS12 base equipment will start an unprecedented SIDIS program with kaons, giving insights to the strange flavor dependence of the TMDs. Hall C with its "pinhole" magnetic spectrometer pair would add precision cross sections and their ratios for both pions and kaons. The rigid connection to the pivot allows for longitudinal-transverse separations, unique amongst the Hall experimental setups. Given the relative simplicity to change the magnet polarities, and the anticipated large reproducibility and systematic understanding of the spectrometer setup, Hall C will be the best place

for 1%-level measurements of  $\pi^+/\pi^-$  ratios, or kaon ratios, and due to its precision will allow for longitudinal-transverse separations, unique amongst the Hall experimental setups. Disadvantage of the setup is the lack of full azimuthal coverage at larger  $p_T$ . The multi-pronged SIDIS approach combining foreseen 12-GeV experiments in large acceptance Hall B and precision Hall C will be presented.

## WG2 Small-x, Diffraction and Vector Mesons / 288

### ALICE results on ultra-peripheral p-Pb and Pb-Pb collisions

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Ultra-relativistic heavy ions generate strong electromagnetic fields, which offer the possibility to study gamma-gamma, gamma-nucleus and gamma-proton processes at the LHC in ultra-peripheral Pb-Pb and p-Pb collisions (UPC). Exclusive photoproduction of vector mesons is sensitive to the gluon distribution of the interacting target (proton or nucleus). The reactions allow one to study saturation phenomena (p-Pb) and nuclear gluon shadowing (Pb-Pb).

Here we present results from the ALICE measurement of coherent photoproduction in Pb-Pb UPC at  $\sqrt{s_{NN}} = 2.76$  TeV of  $J/\psi$  mesons at forward and central rapidity and  $\rho^0$  and  $\psi(2S)$  mesons at central rapidity. Furthermore, we also show our results on the  $J/\psi$  photoproduction in p-Pb UPC at  $\sqrt{s_{NN}} = 5.02$  TeV in the forward and backward rapidities where the rapidity is measured in the laboratory frame with respect to the proton beam direction.

## WG4+WG5 Joint Session / 289

### Measurement of forward-backward asymmetries of $B^+$ , $\Lambda_b$ and $\Lambda$ in ppbar collisions at $\sqrt{s}=1.96$ TeV

**Author:** Braden Keim Abbott<sup>1</sup>

<sup>1</sup> *University of Oklahoma (US)*

We present a measurement of the forward-backward asymmetry in the production of  $B^\pm$  mesons,  $\Lambda_b$  baryons and  $\Lambda$  baryons in  $10.4 \text{ fb}^{-1}$  of ppbar collisions at  $\sqrt{s}=1.96$  TeV collected by the D0 experiment during Run II of the Tevatron collider. Nonzero asymmetries would indicate a preference for a particular flavor, i.e., b quark or b antiquark, to be produced in the direction of the proton beam. These measurements provide important constraints on the production mechanisms of heavy quarks at hadron colliders.

## WG7 Future experiments / 291

### MEIC Detector and Interaction Region at JLab

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The Electron-Ion Collider (EIC) is envisioned as the next-generation US facility for exploring the strong interaction. The Medium-energy EIC (MEIC) is the first stage of the EIC at Jefferson Lab (JLab), aimed at mapping the spin and spatial structure of the quark and gluon sea in the nucleon, understanding the emergence of hadronic matter from color charge, and probing the gluon fields in nuclei. A full-acceptance detector is designed to measure the complete final state. Its interaction region allows spectators tagged with high resolution to catch all nuclear and partonic target fragments. The combination of a high luminosity, polarized lepton and ion beams, and detectors fully integrated with the accelerator will allow MEIC a unique opportunity to make a breakthrough in nucleon structure and QCD dynamics.

**WG6 Spin Physics / 292**

## **Towards a Direct Measurement of the Quark Orbital Angular Momentum Distribution**

**Author:** simonetta liuti<sup>1</sup>

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We discuss the canonical ( $J_i$ ) and kinetic/mechanical (Jaffe and Manohar) definitions of partonic orbital angular momentum (OAM). It was recently shown by Hatta and Burkardt that the two definitions correspond to the second moment in intrinsic  $k_T$  of the same generalized transverse momentum distribution (GTMD), while they differ in their gauge link structure. At the same time, as first observed by Polyakov, canonical orbital angular momentum can be independently described in terms of a twist three generalized parton distribution, which only a straight type of gauge link is allowed for. Here we provide further insight into this problem by showing that the second moment in  $k_T$  of the OAM twist two GTMD and twist three GPD, are connected through a Wandzura Wilzcek type relation which generalizes the one originally developed for the polarized twist three distribution,  $g_T$ . An important outcome of the picture we provide is that the two different mechanisms for generating partonic OAM can be both tested experimentally and validated by lattice calculations. Additional calculations using the Reggeized Diquark model are shown that provide an initial guidance for assessing the size of the various contributions.

**WG1 Structure Functions and Parton Densities / 293**

## **Experimental Investigation of the Structure Functions of Bound Nucleons**

**Author:** Arie Bodek<sup>1</sup>

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We present results from a high precision experimental study of the nuclear modification of the longitudinal ( $\sigma_L$ ) and transverse ( $\sigma_T$ ) structure functions of nucleons bound in nuclear targets. The origin of these modifications (commonly referred as the EMC effect) is not fully understood. Our

measurements of  $R = \sigma_L / \sigma_T$  for nuclei ( $R_A$ ) and for deuterium ( $R_D$ ) indicate that nuclear modifications of the structure functions of bound nucleons are different for the longitudinal and transverse structure functions, and that  $R_A < R_D$  (which contrary to expectation from several theoretical models). The results could be interpreted as evidence for the softening of both the parallel and transverse momentum quarks in the nucleon, possibly resulting from partial quark de-confinement due to short range correlations. This additional nuclear effect should be implemented in cur

### WG3:Electroweak Physics and Beyond the Standard Model / 294

## Forward-Backward Asymmetry as a Discovery Tool for Z' Bosons at the LHC

**Author:** Elena Accomando<sup>1</sup>

**Co-authors:** Alexandre Belyaev<sup>1</sup>; Claire Shepherd-Themistocleous<sup>2</sup>; Juri Fiaschi<sup>1</sup>; Ken Mimasu<sup>3</sup>; Stefano Moretti<sup>1</sup>

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The Forward-Backward Asymmetry (AFB) in Z' physics is commonly only perceived as the observable which possibly allows one to interpret a Z' signal by distinguishing different models of such (heavy) spin-1 bosons. In this talk, we examine the potential of AFB in setting bounds on or even discovering a Z' boson at the Large Hadron Collider (LHC) and show that it might be a powerful tool for this purpose. We analyse two different scenarios: Z' bosons with a narrow and wide width, respectively. We find that, in the first case, the significance of the AFB search can be comparable with that of the bump search usually adopted by the experimental collaborations; however, being a ratio of (differential) cross sections the AFB has the advantage of reducing systematical errors. In the second case, the AFB search can win over the bump search in terms of event shape, as the structure of the AFB distribution as a function of the invariant mass of the reconstructed Z' boson could nail down the new broad resonance much better than the event counting strategy usually adopted in such cases.

The talk would be based on the recently published paper arXiv:1503.02672

### WG1 Structure Functions and Parton Densities / 295

## Using Drell-Yan forward-backward asymmetry to constrain Parton Distribution Functions

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We show that measurements of the forward-backward charge asymmetry ( $A_{FB}(M)$ ) of Drell-Yan dilepton events produced at hadron colliders can be used to constrain Parton Distribution Functions (PDFs). PDF uncertainties are the dominant systematic error in the extraction of of electroweak parameters from hadron collider data. These parameters include the electroweak mixing angles ( $\sin^2 \theta_{eff}^{lept}(M_Z)$ , and  $\sin^2 \theta_W$ ) and the mass of the W boson. The  $\chi^2$  values for fits using different

NNPDFs in the extraction of  $\sin^2 \theta_{eff}^{lept}(M_Z)$  and  $\sin^2 \theta_W$  from  $A_{FB}(M)$  measurements can be used to place additional constraints on PDFs. In turn, using these constrained PDFs significantly reduces the PDF errors in the extraction of electroweak parameters.

#### WG4 QCD and Hadronic Final States / 296

### NNLL Resummation of Event-Shapes in $e^+e^-$ Annihilation

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Event shape observables are essential tools for studying the behaviour of high energy QCD. Yet in the region where soft and collinear gluon emission is most dominant, standard perturbation theory is rendered unreliable and the series must be resummed to all orders in the strong coupling. We have recently developed a general method for the resummation of event shapes, in  $e^+e^-$  annihilation, at next-to-next-to-leading logarithmic accuracy. We implement the novel method semi-numerically and reproduce four already-known predictions, as well as producing three new results. We match our findings to fixed-order results, up to NNLO.

#### WG6+WG7 joint session / 297

### SoLID-SIDIS: Future Measurements of Transverse Spin, TMDs and more

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(for the SoLID Collaboration) With the Jefferson Lab 12 GeV electron beam and the proposed Solenoidal Large Intensity Device (SoLID) in Hall A, several newly approved experiments will perform measurements of both the single and double spin asymmetries via semi-inclusive deep inelastic scattering (SIDIS) from polarized  $^3\text{He}$  ("neutron") and proton targets. The large acceptance and high luminosity features of the SoLID will enable the extraction of Collins, Sivers, Pretzelosity asymmetries and more with unprecedented precision in multi-dimensional kinematic binning. The measurements from these experiments will also provide important information about the transverse momentum dependent parton distribution functions (TMDs). In this talk, we will discuss these experiments followed by an overview of the SoLID instrumentation. New physics opportunities of using the SoLID will be presented at the end.\footnote{This work is supported in part by the U.S. Department of Energy under Contacts No. DE-FG02-03ER41231}.

#### WG5 Heavy Flavours / 298

## Measurements of open heavy-flavour production in pp and p-Pb collisions with ALICE

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In hadronic collisions, heavy quarks (charm and beauty) are produced in hard scattering processes with large momentum transfer. The measurement of the production cross sections of heavy-flavour hadrons in pp collisions provides an important test of pQCD calculations. Some insight into the role of multi-parton interactions (MPI) and the interplay between hard and soft mechanism for particle production can be obtained by studying heavy-flavour production as a function of multiplicity of charged particles produced in these collisions. The measurement in pp collisions also provides a crucial baseline for heavy-ion collisions.

In p-Pb collisions, heavy-quark production is expected to be sensitive to cold nuclear matter effects, such as the modification of parton distribution functions in nuclei compared to nucleons and  $k_T$  broadening or energy loss in cold nuclear matter. To better understand the relation between cold nuclear matter effects and the number of particles produced in the collision, heavy-flavour production can be studied as a function of charged-particle multiplicity.

With the ALICE detector at the LHC, heavy-flavour production is studied by reconstructing  $D^0$ ,  $D^+$ ,  $D^{*+}$  and  $D_s^+$  mesons via their hadronic decay channels and, alternatively, via the measurement of leptons (electrons and muons) from semi-leptonic decays of heavy-flavour hadrons.

In this contribution, we present results on open heavy-flavour production cross sections and their dependence on charged particle multiplicity in pp ( $\sqrt{s} = 2.76$  TeV and  $\sqrt{s} = 7$  TeV) and p-Pb collisions ( $\sqrt{s_{NN}} = 5.02$  TeV). We also present azimuthal correlations of D mesons and heavy-flavour decay electrons with charged hadrons in pp and p-Pb collisions.

WG3+WG7 Joint Session / 299

## Precision Measurements of Parity-Violation in Deep Inelastic Scattering using SoLID

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A new proposal to measure parity violating deep inelastic asymmetry (PVDIS) will provide a precision test of the Standard Model through an unique constraints on axial-vector neutral quark current couplings and a precision measurement of the weak mixing angle. We plan to measure the asymmetry to about 0.5% precision over the Bjoken  $x$  from 0.3 to 0.7 where the PV asymmetry is approximately independent of hadronic structure. If any deviations observed, the residual hadronic and new physics contributions in the asymmetry could be separated by kinematic dependence of the PVDIS asymmetry. At the proposed precision level, asymmetry will be sensitive to novel hadronic structure effects including charge symmetry violation (CSV) effects and higher twist effects. Observation of these effects itself will be beneficial to building better theoretical models. A deuterium target will be used for Standard Model tests while a d/u quark distribution ratio measurement is proposed using a hydrogen target.

The broad reach in kinematic and high statistical precision at which PVDIS asymmetries are planned to measure, a large angle acceptance, high luminosity, and large azimuthal acceptance device is a necessity. We are proposing a new spectrometer based on a solenoid magnet called Solenoidal Large

Intensity Device (SoLID) that will provide broad range of electroweak and QCD physics measurements to be conducted at the Jefferson Laboratory. The apparatus will have set of tracking gas electron multiplier (GEM) detectors, a gas Cerenkov detector, and a sampling electromagnetic calorimeter to provide particle identification. The experiment will be conducted as a high rate counting mode experiment.

**WG2 Small-x, Diffraction and Vector Mesons / 300**

## **Exclusive and inclusive photonuclear interactions at the LHC**

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Particle production through photon-induced processes in ultra-peripheral collisions has attracted an increasing interest following the first heavy-ion runs at the CERN Large Hadron Collider. The increased collision energy compared with the Relativistic Heavy-Ion Collider (RHIC) at BNL implies that also heavy final states can be produced in abundance. The focus has so far been on exclusive production of vector mesons, i.e. reactions of the type  $A+B \rightarrow A+B+V$ , where the vector meson is produced in a photonuclear interaction. This has been studied in Pb+Pb and p+Pb as well as p+p interactions.

This presentation will give a summary of the models available for exclusive vector meson production in ultra-peripheral collisions. Most calculations have concentrated on the production cross section as a function of rapidity,  $d\sigma/dy$ , as this is believed to serve as a probe of the nuclear/nucleon gluon distribution when a heavy vector is produced. But a full description of the reaction dynamics requires that also the transverse momentum and invariant mass distributions are reproduced. How these latter quantities can be modelled will be addressed in this presentation. Finally, models for more general photonuclear/photon-nucleon interactions, such as photoproduction of heavy quarks and jets, will be briefly discussed.

**WG2 Small-x, Diffraction and Vector Mesons / 301**

## **Ultra peripheral vector meson production from PbPb Collisions at 2.76 TeV**

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The nature of the initial state can be studied in photon-nucleus collisions at the LHC. Ultra-peripheral collisions (UPCs) of heavy ions involve long range electromagnetic interactions at impact parameters larger than twice the nuclear radius. At TeV energies, the strong electromagnetic field due to the coherent action of the  $Z=82$  proton charges generates a large flux of photons, which can be used for high-energy photoproduction studies. Heavy vector mesons (for example  $J/\psi$ ,  $\Psi'$ , Upsilon) produced in electromagnetic interactions provide direct information on the parton distribution functions in the nucleus at very low values of Bjorken- $x$ . These events are characterized by a very low hadron multiplicity. The wide pseudorapidity coverage of the CMS detectors is used to separate such events from very peripheral nuclear interactions. The CMS experiment has excellent capabilities for the measurement of the heavy vector mesons in the dimuon decay channel using the tracker and the muon chambers. This analysis demonstrates CMS's capabilities for measuring  $J/\psi$ ,  $\psi'$  and



the two-photon process in ultra-peripheral collisions, using the 2011 PbPb and 2013 pPb data. The measured coherent J/psi photoproduction cross section in ultra-peripheral Pb-Pb collisions will be presented. The prospects for future measurements using the data to be collected in the 2015 PbPb run will be described.

**WG2 Small-x, Diffraction and Vector Mesons / 302**

## **Detection of CC "0 pion" neutrino interactions in LAr TPC with the ArgoNeuT detector**

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The analysis and interpretation of the present and future neutrino oscillation experiments strongly rely on the quantitative understanding of neutrino and antineutrino interactions with nuclei in the "few GeV" energy range. With the advent of the Liquid Argon Time Projection Chamber (LArTPC) experimental techniques for neutrino detection, a novel approach and methodology in neutrino data analysis is now being developed. We will illustrate this method, as based on categorization of  $\nu_\mu$  CC "zero pion" events into experimental exclusive topologies, rather than on MC driven classification of the event rates in terms of interaction channel. Data collected by the ArgoNeuT experiment in the "few-GeV" energy range are extremely helpful to directly probe features of neutrino interactions and associated nuclear effects in the range of interest for future long-baseline neutrino oscillation experiments.

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## **Transverse momentum dependent (un)polarized gluon distributions in Higgs production**

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**Co-authors:** Cristian Pisano<sup>2</sup>; Miguel G. Echevarría<sup>3</sup>; Piet Mulders<sup>4</sup>

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We discuss transverse momentum dependent (un)polarized gluon distributions (gluon TMDs) and their proper definitions in the context of factorization theorems. All the gluon TMDs have a scale evolution driven by a universal evolution kernel which is resummed to NNLL. By an explicit NLO calculation of the three gluon TMDs which are matched onto leading twist parton distribution functions (PDFs) we demonstrate that they are free from rapidity divergences, and calculate the Wilson coefficients of their expansion in terms of the PDFs. We investigate the effects of evolution and discuss their impact on the transverse momentum spectrum of color singlet production, such as Higgs boson production in gluon fusion.

**WG6 Spin Physics / 304**

## **Polarization in double parton scattering**

**Author:** Tomas Kasemets<sup>1</sup>

<sup>1</sup> DESY

We discuss the impact of double parton scattering at the LHC. In particular we focus on the impact of polarization, arising from the spin correlations between two partons inside an unpolarized proton. We demonstrate that the effects can be large in certain kinematic regions and processes and compare our results to data. We further discuss angular asymmetries and similarities as well as differences to the more developed field of spin asymmetries in transverse momentum dependent single parton scattering.

WG4+WG5 Joint Session / 305

## Heavy flavors on CT14

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The LHC is the hadron collider with highest energy in the history. Taking the LHC run 1 data into account and considering more flexible parametrization, the CTEQ-TEA group study its impact on Parton distribution function, the CT14 PDFs. In this talk, we will present the recent study on heavy flavors base on the preliminary CT14 candidate.

WG3:Electroweak Physics and Beyond the Standard Model / 306

## BSM Phenomenology at Run 2 and Beyond

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We provide an overview of the state of beyond-the-Standard Model phenomenology at the beginning of Run 2, with a particular focus on phenomena associated with naturalness of the weak scale. We also briefly survey the prospects for probing naturalness at future high-energy colliders.

WG1 Structure Functions and Parton Densities / 307

## Light quark flavor asymmetry and quark energy loss at Fermilab E906 Experiment

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Fermilab E906/SeaQuest is a fixed-target dimuon experiment using the 120 GeV proton beam from the Fermilab Main Injector. We have completed the first physics run in 2014 and continue collecting high statistic data samples of p+p, p+d, p+C, p+Fe and p+W collisions. E906 measures J/Psi, Psi' and Drell-Yan yields in the dimuon channel over a wide range of kinematic coverages, which is optimal

for studying light flavor asymmetry and quark energy loss effects in Drell-Yan. E906 has successfully reconstructed the dimuon mass spectrum with clear  $J/\Psi$  and  $\Psi'$  signals from the latest 2014 data. We expect the results will shed new light on our understanding of the nucleon structure and the nature of quark energy loss in nuclear medium in p+A collisions. In this talk, we will discuss the current status and preliminary results.

**WG6 Spin Physics / 308**

## Exclusive mesoproduction of lepton pair $\pi^- p \rightarrow \ell^+ \ell^- n$ to probe GPDs at J-PARC: power corrections and lepton angular distribution

**Author:** Kazuhiro Tanaka<sup>None</sup>

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The measurement of exclusive mesoproduction of lepton pair,  $\pi^- p \rightarrow \ell^+ \ell^- n$ , may be performed using the high-intensity pion beams at J-PARC in the near future. The leading hard exclusive amplitude for this process was obtained by E.R. Berger, M. Diehl, and B. Pire [Phys. Lett. B 523 (2001) 265] in terms of the partonic subprocess convoluted with the relevant nonperturbative functions, the nucleon GPDs and the pion distribution amplitudes. The result is associated with the nonperturbative functions of twist two and with the longitudinally polarized virtual photon which is produced by quark-antiquark annihilation and decays into a lepton pair. It was also pointed out that the contributions associated with the transversely polarized virtual photon are suppressed by the inverse powers of the dilepton mass  $Q$ , compared to the leading amplitude; such power corrections could play important roles for the J-PARC kinematics but have not been studied in the literature.

We derive the relevant exclusive amplitudes associated with the transversely polarized virtual photon, taking into account the twist-three nonperturbative functions, and show that the interference of this amplitude from transverse photon and the leading amplitude from longitudinal photon yields the first ( $1/Q$ ) power correction to the cross section, which exhibits the lepton angular distribution different from the leading contribution. We also discuss the endpoint behavior of the relevant convolution integral involved in the cross section and give an estimate of the size of the  $1/Q$  power correction.

**WG6 Spin Physics / 309**

## Twist-3 spin observables for single-hadron production in DIS

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**Co-authors:** Daniel Pitonyak<sup>2</sup>; Koichi Kanazawa<sup>1</sup>; Marc Schlegel<sup>3</sup>

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In this talk we will address new theoretical work on twist-3 spin asymmetries for the process  $l + N \rightarrow h + X$ , for which recent data have been obtained. Specifically, we will address the longitudinal-transverse double-spin asymmetry  $A_{LT}$ , and the transverse single-spin asymmetry  $A_N$  for a polarized final state hyperon. Open questions and future prospects will be mentioned as well.

**WG7 Future experiments / 310****The Mu2e Experiment at Fermilab****Author:** Franco Grancagnolo<sup>1</sup><sup>1</sup> *INFN Lecce*

The Mu2e Experiment at Fermilab will search for coherent, neutrinoless conversion of muons into electrons in the field of a nucleus with a sensitivity improvement of a factor of 10,000 over previous experiments. Such a lepton flavor-violating reaction probes new physics at a scale inaccessible with direct searches at either present or planned high energy colliders. The experiment both complements and extends the current search for muon decay to electron+gamma at MEG and searches for new physics at the LHC. We will present the physics motivation for Mu2e, the design of the muon beamline and the detector, and the current status of the experiment.

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**Low mass dilepton production at high pt in color glass condensate****Author:** Zhongbo Kang<sup>1</sup><sup>1</sup> *Los Alamos National Laboratory***Corresponding Author:** kangphy@gmail.com

In this talk, we will demonstrate the conventional small-x/color glass condensate (CGC) formalism contains large logarithms  $\log(pt/M)$  when the dilepton mass is much smaller than its transverse momentum  $M \ll pt$ . We propose a new factorization formalism within the small-x approach to resum these large logarithms to all orders and make numerical calculations relevant to both RHIC and LHC energies.

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**Advances on TMD evolution and global analysis****Author:** Zhongbo Kang<sup>1</sup><sup>1</sup> *Los Alamos National Laboratory***Corresponding Author:** kangphy@gmail.com

I will present the recent developments/status of transverse momentum dependent (TMD) evolution and global analysis of TMD extractions, as well as the future perspective. I will compare different approaches and discuss their phenomenological consequences (in a case study of Siverson's asymmetry), and point out what's needed in the future global analysis.

**WG6 Spin Physics / 314**

## Challenges in the extraction of TMDs from SIDIS data: perturbative vs non-perturbative aspects

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In order to describe SIDIS over a wide region of transverse momentum  $q_T$ , one must confront both the perturbative and non-perturbative regimes. In this sense, when extracting the non-perturbative TMDs from experimental data, one should ensure that there exists a smooth transition between the soft gluon resummation regime and the pQCD predictions, at large  $q_T$ . We present recent results on the matching of these two regimes in different kinematical configurations in SIDIS.

WG6 Spin Physics / 315

## Transverse Force on Quarks in DIS

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Transverse single-spin asymmetries are not the only observable where the transverse force on quarks in DIS plays a role. For example, higher-twist effects in polarized inclusive DIS can be related to that force. Furthermore the torque due to that force is relevant when comparing the Jaffe-Manohar with the  $J_i$  definition for quark orbital angular momentum. I explain the origin of that force in semi-classical pictures and discuss connections and differences with the Aharonov-Bohm effect.

WG6 Spin Physics / 316

## Linear polarization of gluons and Higgs plus jet production at the LHC

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We consider Higgs plus jet production as a process that is sensitive to the linear polarization of gluons inside the unpolarized protons of the LHC. The leading order expressions for the transverse momentum distribution of the Higgs plus jet pair are calculated in terms of transverse momentum dependent quark and gluon distributions. Both angular independent and azimuthal angular dependent contributions are presented directly in the laboratory frame. Lacking experimental constraints on the linearly polarized gluon distribution, we study its effects on Higgs plus jet production using two different models to illustrate the generic features and maximal effects. It is found that the  $\cos 2\phi$  distribution may be the most promising observable, as it is driven by only one initial linearly polarized gluon.

WG3+WG7 Joint Session / 317

## ”Flavor violating signatures of lighter and heavier Higgs bosons within Two Higgs Doublet Model type III at the LHeC

**Authors:** Jaime Hernandez<sup>1</sup>; Jaime Hernández<sup>2</sup>

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We study the prospect for observing the lightest and heavier CP-even neutral Higgs bosons ( $\phi = h$  and  $H$ ) in their decays to flavor violating  $bs^*$  (with charge conjugation) at the proposed Large Hadron electron Collider (LHeC), with center-of-mass energy approximately 1.296 TeV, in the framework of the Two Higgs Doublet Model Type-III, assuming a four-zero texture in the Yukawa matrices and a general Higgs potential. We consider scenarios in agreement with the current experimental data of flavor physics constraints and Higgs physics. We consider the charge current production processes:  $\nu e \phi qf$ , with the flavor violating decays of the Higgs bosons, that leads to 3-jets + E/T. We find that the SM Higgs boson,  $h$ , would be shown up within the some scenarios of our model, approximately  $1-2\sigma$  at the LHeC, with 100 fb<sup>-1</sup> of data. We also find that second heavier neutral Higgs boson,  $H$ , with mass 150 GeV would have  $1-\sigma$  significances. We expect that our finding will show up at LHeC with the designed luminosity, if the latter is upgraded by a factor of 2-3. This leads to significances of  $2-3\sigma$  and hence one can argue that the scenarios of our model could be the most viable extension of the 2HDMs with Flavour Changing Neutral Currents generated at tree level and controlled by the four-zero texture approach in the Yukawa matrices.

WG6 Spin Physics / 318

## Recent Spin structure results from inclusive electron scattering experiments at Jefferson Lab.

**Author:** Nilanga Liyanage<sup>1</sup>

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Jefferson lab is well known for its high quality, high polarization electron beam. Jefferson lab polarized beam, combined with the range of polarized proton, deuteron and <sup>3</sup>He targets in experimental halls A, B and C, allows for high precision exploration of spin structures of both proton and neutron in the low to intermediate Q<sup>2</sup> region. The impact of Jefferson lab precision spin data is especially significant in the high x<sub>Bj</sub> valence quark region, where the availability of previous world is rather limited. Many exciting new results on spin structure functions g<sub>1</sub> and g<sub>2</sub>, virtual photon asymmetry A<sub>1</sub>, and the moments of the spin structure functions have recently become available from halls A, B and C for both neutron and proton. I will be presenting results from hall A experiments small angle GDH (E97-110) and g<sub>2p</sub> (E08-027), hall B experiments EG1b, EG1-DVCS and EG4 as well as from hall C SANE (E07-003) experiment.

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## Heavy flavour spectroscopy at LHCb

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**WG1 Structure Functions and Parton Densities / 320**

## **The Gottfried Sum Rule Revisited**

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**WG1+WG5 Joint Session / 321**

## **New Limits on Intrinsic Charm in the Nucleon from Global Analysis**

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## **Physics with Jets at LHCb**

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**WG1 Structure Functions and Parton Densities / 323**

## **Vector Boson Production with Heavy Ions at the LHC**

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**WG1 Structure Functions and Parton Densities / 324**

## **Impact of Global Direct Photon Data on the Gluon Distribution Function**

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**WG1 Structure Functions and Parton Densities / 325**

## **Transverse Momentum Dependent (Un)polarized Gluon Distribution in Higgs Production**

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**WG2 Small-x, Diffraction and Vector Mesons / 326**

## **Matching Collinear and Small-x Factorization Calculations for Inclusive Hadron Production in pA Collisions**

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We construct a theoretical framework to match the formulas for forward inclusive hadron productions in pA collisions in the small-x saturation formalism and collinear factorization. The small-x calculation can be viewed as a power series in  $Q^2s/k_{\perp}^2$ , in which the collinear factorization result corresponds to the leading term. At high transverse momentum, the subleading correction terms are insignificant, whereas at low  $p_{\perp}$ , the power corrections become important and the small-x resummation is essential to describe the differential cross section. We show that the familiar collinear factorization calculation can smoothly match the results from small-x factorization at next-to-leading order in  $\alpha_s$  when we use exact kinematics, as opposed to the approximate kinematics in previous work. With this matching, we can describe the experimental data from RHIC very well at high  $p_{\perp}$ .

**WG7 Future experiments / 327**

## **Round table discussion about future lepton-ion colliders : synergies and complementarity**

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**SOLID-PVDIS**



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## **Prospects for $K^+ \rightarrow \pi^+ \nu \nu$ observation at CERN in NA62**

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## **Polarized Drell-Yan measurements at Fermilab: the future of the Seaquest experiment (136)**

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## **An Opportunity for Forward Jet Single Spin Asymmetry Measurements at RHIC (141)**

**WG4 QCD and Hadronic Final States / 332**

## **Results and developments on (N)NLO+PS matching**

**Author:** Stefan Prestel<sup>1</sup>

<sup>1</sup> *Deutsches Elektronen-Synchrotron (DE)*

This contribution reviews recent developments in matching higher-order perturbative QCD calculations to parton-shower event generators.

**WG3+WG4 Joint session / 333**

## **Off-Shell Higgs Boson Production and Higgs Width Bounds**

**Author:** Richard Keith Ellis<sup>1</sup>

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The current status of theoretical predictions for off-shell Higgs boson production and the implications for bounds on the Higgs boson width are reviewed.

**WG3:Electroweak Physics and Beyond the Standard Model / 334**

## **Exclusion and Discovery via Drell-Yan in Multi-Z ' Models**

**Author:** Juri Fiaschi<sup>1</sup>

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

Di-lepton production at hadron colliders is by far the preferred channel to search for  $Z'$  bosons. Traditionally, such searches have exploited the Narrow Width Approximation (NWA) for the signal, thereby neglecting the presence of both ( $Z'$ ) finite width and interference (with the Standard Model) effects. Furthermore, the primary observable used has traditionally been the cross section, potentially enabling the extraction of the  $Z'$  resonance in the invariant mass of the di-lepton system. Progress has occurred recently though, which has modified the above paradigm. Indeed, it has been established that both finite width and interference effects ought to be taken into account in experimental searches while still retaining the model independent approach ensured by the NWA. We are showing these effects in a Composite Higgs Model scenario, which represent a realistic and well motivated framework that naturally provides a spectrum with multiple  $Z'$  bosons.

**WG6 Spin Physics / 335**

## New Deeply Virtual Compton Scattering results from Jefferson Lab

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Deeply Virtual Compton Scattering (DVCS) is the easiest reaction that probes the Generalized Parton Distributions (GPDs) of the nucleon. GPDs offer the exciting possibility of mapping the 3-D internal structure of protons and neutrons by providing a transverse image of the constituents as a function of their longitudinal momentum.

An extensive experimental program is currently pursued at Jefferson Lab to access GPDs through DVCS. New results from Hall A and Hall B recently released will be shown and discussed. Special attention will be devoted to the applicability of the GPD formalism at the moderate values of momentum transfer ( $Q^2$ ) available at Jefferson Lab, and the necessity of higher twist corrections in order to fully describe the extremely precise data from these dedicated high luminosity experiments.

An outlook of additional DVCS experiments under analysis and planned with the future Upgrade of Jefferson Lab to 11 GeV will be also presented.

**WG3+WG5 Joint Session / 336**

## New physics searches with B mesons at the ATLAS experiment

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The large amount of Heavy Flavour data collected by the ATLAS experiment is potentially sensitive to New Physics, which may be found in the mixing of B meson states, or through processes that are naturally suppressed in the Standard Model. We present the most recent results on the measurement of the decay of the Bs into J/psi phi based on full data collected in LHC Run-1 and with updated flavour tagging improving the accuracy in the CP-violating phase  $\phi_{1s}$ . We also present the measurement of the decay time difference in the Bd system. The most recent results on the search for the rare decay Bs (B0)  $\rightarrow \mu^+\mu^-$  are presented as well as results on the angular distribution parameters AFB and FL describing the decay Bd  $\rightarrow K^*\mu^+\mu^- \rightarrow K\pi\mu^+\mu^-$ .

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## Discussion

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### Recent Developments of the fastNLO Toolkit

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### Solving the NLO BK equation in coordinate space

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We present results from a numerical solution of the next-to-leading order (NLO) Balitsky-Kovchegov (BK) equation in coordinate space in the large  $N_c$  limit. We show that the solution is not stable for initial conditions that are close to those used in phenomenological applications of the leading order equation. We identify the problematic terms in the NLO kernel as being related to large logarithms of a small parent dipole size, and also show that rewriting the equation in terms of the “conformal dipole” does not remove the problem. Our results qualitatively agree with expectations based on the behavior of the linear BFKL equation.

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### Solving the NLO BK equation in coordinate space

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### Low-x physics at LHeC/FCC-he and its implications on UHECR

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### High-energy evolution of Wilson lines at the next-to-leading order