

9th International Workshop on Multiple Partonic Interactions at the LHC

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Book of Abstracts

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WG3: Double Parton Scatterings / 1

Double-Parton-Scattering Theory Studies with quarkonia

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I will review the status of theory studies of Double Parton Scatterings (DPS) using associated production of quarkonia at colliders. This includes $J/\psi + J/\psi$, $\Upsilon + \Upsilon$, $J/\psi + \Upsilon$, $J/\psi + W$, $J/\psi + Z$, $\Upsilon + D$ and $J/\psi + D$. Where relevant, I will discuss the impact of QCD corrections to Single Parton Scatterings which can affect the extraction of the DPS yield. I will also discuss specific observables related to the quarkonium polarisation and the feed-down pattern which can help verify the dominance of either SPS or DPS contributions in a given kinematical region.

WG1: Minimum Bias and Underlying Event / 5

Latest Minimum Bias and Underlying Event Measurements with the ATLAS Detector

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While the modelling of Minimum Bias (MB) is a crucial ingredient to learn about the description of soft QCD processes, the studies of the Underlying Event (UE) shed light on the description of both soft and hard QCD processes at hadron colliders. The ATLAS collaboration has provided measurements of the inclusive charged-particle multiplicity and its dependence on transverse momentum and pseudorapidity in special data sets with low LHC beam currents, recorded at center-of-mass energies of 8 TeV and 13 TeV. Moreover, results on the number and transverse-momentum sum of charged particles as a function of the leading high pT track in events taken at a center-of-mass energy of 13 TeV are presented. These results are separated in the towards, transverse, and away from the leading track and allow to test the modelling of the Underlying Event in modern MC generators. Furthermore, event-shape variables based on charged particles have been measured in Z-events and have been compared with the predictions of different state-of-the-art MC generators. These measurements test the Underlying Event in a complementary way.

WG1: Minimum Bias and Underlying Event / 6

Jet Substructure Measurements Sensitive to Soft QCD effects with the ATLAS Detector

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Calculations of jet substructure observables which are accurate beyond leading-logarithmic accuracy have recently become available. Such observables are significant not only for probing a new regime of QCD at a hadron collider, but also for improving the understanding of jet substructure properties that are used in many studies at the Large Hadron Collider. In this talk, we discuss first measurement of jet substructure quantities at a hadron collider, calculated at next-to-next-to-leading-logarithm

accuracy. The soft drop mass is measured in dijet events with the ATLAS detector at 13 TeV, unfolded to particle-level and compared to Monte Carlo simulations. In addition, we present a measurement of the splitting scales in the kt jet-clustering algorithm for final states containing a Z-boson candidate at a centre-of-mass energy of 8 TeV. The data are also corrected for detector effects and are compared to state-of-the-art Monte Carlo predictions.

WG4: Small-x and Diffraction / 8

Elastic and Inelastic Cross Section Measurements with the ATLAS Detector

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The total pp cross section is a fundamental property of the strong interaction which can not be calculated in perturbative QCD but only described based on phenomenological models. The ATLAS collaboration has measured the total inelastic proton-proton cross section and the diffractive part of the inelastic cross section at 13 TeV in special data sets taken with low beam currents and using forward scintillators. More precise measurements of the total pp cross section and the elastic and inelastic contributions have been extracted from measurements of the differential elastic cross section using the optical theorem. The ATLAS Collaboration has performed this measurement in elastic data collected with high beta* optics at 8 TeV centre-of-mass energy with the ALFA Roman Pot detector.

WG2: MC Development and Tuning / 11

Studies of Top Quark Monte Carlo Modelling

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The status of recent studies of modern Monte Carlo generator setups for the pair production of top quarks at the LHC. Samples at a center of mass energy of 13 TeV have been generated for a variety of generators and with different generator configurations. The predictions from these sample are compared to ATLAS data for a variety of kinematic observables.

WG2: MC Development and Tuning / 12

Studies of Monte Carlo modelling of Jets

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The predictions of different Monte Carlo generators for QCD jet production, both in multijets and for jets produced in association with other objects, are presented. Recent improvements in showering Monte Carlos provide new tools for assessing systematic uncertainties associated with these jets. Studies of the dependence of physical observables on the choice of shower tune parameters and new prescriptions for assessing systematic uncertainties associated with the choice of shower model and tune are presented.

WG6: Interactions with Nuclei / 17

PHENIX results on azimuthal correlations in small collision systems from the RHIC geometry and energy scan

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Collective behavior in small collision systems has been explored in detail by the PHENIX experiment using the unique RHIC capability to collide different species at a variety of center-of-mass energies. Measurement of azimuthal anisotropies, $v_2(pT)$, and long-range two-particle correlations are studies in p+Al, p+Au, d+Au, and 3He+Au at 200 GeV with inclusive charged particles and identified pions and protons at mid-rapidity. The triangular anisotropy, $v_3(pT)$, is also measured in central d+Au, and 3He+Au collisions. The 2016 beam energy scan of d+Au collisions at 19.6, 39.0, 62.4, and 200 GeV provided a high-statistics data set that enabled multiparticle cumulant analyses of $v_2\{2\}$, $v_2\{4\}$, $v_2\{6\}$ as a function of event multiplicity, as well as the study of v_2 of inclusive hadrons as a function of pseudorapidity over 6 units of η . These measurements taken together provide a wealth of information sensitive to initial vs final state effects, nonflow and flow correlations, longitudinal and transverse partonic and hadronic dynamics. Detailed model comparisons with all observables will be discussed.

WG2: MC Development and Tuning / 18

Heavy Ions in Pythia8

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Angantyr is a new model for collisions involving heavy nuclei in Pythia8. It is inspired by the old Fritiof model, but includes more perturbative physics and a more careful consideration of fluctuations in nucleon-nucleon cross sections, and the related diffractive processes. In the current implementation in Pythia8 parton-level nucleon-nucleon minimum bias events are stacked together and hadronised independently, which means no collective effects are modelled, but the plan is to also include string interaction effects, such as string *shoving*, colour reconnection and rope hadronisation (see separate talk) where such effects will be present.

WG2: MC Development and Tuning / 19

The Lund string in dense environments

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In hot and dense environments both in heavy ion collisions and high multiplicity proton-proton events, Lund string fragmentation must be modified to take into account effects from the interaction between strings prior to and in the hadronisation. One such modification is colour reconnections, where oppositely directed colour fields may cancel each other. But there is also a possibility for the string fields to interfere constructively. In the latter case the string tension available for creating q-qbar pairs in each break-up is expected to increase, resulting in a higher probability for producing heavier hadrons. Furthermore, the constructive interference may lead to a repulsion between strings which overlap in space-time, a process we call *shoving*. This can be shown to produce collective effects in proton collisions, such as a long-range near-side ridge.

WG5: High Multiplicities / 20

J/psi production as a function of charged particle multiplicity in ALICE at the LHC

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Details of charmonium production in hadronic collisions are still under active investigation in the scientific community. The event multiplicity dependence of J/psi production will give insight into the processes at the parton level. Multiple Parton Interactions (MPI) are thought to be a substantial source of hard scattering processes at LHC energies. Here, several inelastic scatterings occur at the partonic level in a single pp collision and lead to a strong correlation between particle production and the total event multiplicity. Therefore, MPI may contribute to charmonium production. The ALICE experiment has measured J/psi production as a function of charged particle multiplicity in pp collisions in the dimuon and the dielectron decay channels. A linear increase in J/psi production as a function of charged particle multiplicity is observed. Recently, ALICE has also performed similar kind of studies for pp collisions at $\sqrt{s} = 13$ TeV in the dielectron channel and also in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV in the dimuon channel. The results are compared with the perturbative Quantum Chromodynamics (pQCD) inspired models.

WG5: High Multiplicities / 21

Multiple Partonic Interaction and production of Charmonia in proton+proton collisions at the LHC energies

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In high multiplicity p+p collisions, the Underlying Event observable is of great interest to the scientific community. The Multiple Partonic Interaction (MPI) is one of them, where several inelastic interactions at partonic level occur in a single p+p collision. In general, MPI plays an important role to produce light quarks and gluons. But it is observed that it can also contribute to produce heavy flavor particles like charmonia, when the interaction occurs in a harder scale. This leads to a strong dependence of J/ψ production with charged particle multiplicity. ALICE experiment has observed a monotonic increase of J/ψ with charged particle multiplicity in p+p collisions at $\sqrt{s} = 7, 13$ TeV in dimuon as well as dielectron channels. But, till now the measurements are not available for all the LHC energies. This forbids one to infer about the energy dependence role of MPI on J/ψ production.

In our current study, we have made an effort to understand the role of MPI on multiplicity and energy dependence production of J/ψ using perturbative Quantum Chromodynamics (pQCD) inspired model, PYTHIA8 at different LHC energies of $\sqrt{s} = 0.9, 2.76, 5.02, 7$ and 13 TeV. J/ψ are reconstructed via dimuon channel at forward rapidities ($2.5 < y < 4.0$) and the charged particle multiplicity is measured at midrapidity ($|y| < 1.0$). The effect of Color Reconnection (CR) on the production of J/ψ at the LHC energies at different multiplicity bins is studied. The multiplicity ratio of higher state of charmonia, to J/ψ , i.e. $\psi(2S)/J/\psi$ will be presented as a function of multiplicity at all the LHC energies. We observe the dominance of CR and MPI effects towards high multiplicity events at the LHC energies, showing a threshold of $N_{ch} > 20$. The present study will help in understanding the charmonia production in p+p collisions at the LHC energies.

WG5: High Multiplicities / 22

Particle transverse momentum distributions in p-p Collisions at $\sqrt{s_{NN}} = 0.9$ TeV

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The mid-rapidity transverse momentum spectra of hadrons ($p, K^+, K_s^0, \Lambda, \Lambda\text{-bar}$ and cascade) and the available rapidity distributions of the strange hadrons produced in p-p collisions at LHC energy $\sqrt{s_{NN}} = 0.9$ TeV have been studied using a Unified Statistical Thermal Freeze-out Model (USTFM). The calculated results are found to be in good agreement with the experimental data. The theoretical fits of the transverse momentum spectra using the model calculations provide the thermal freeze-out conditions in terms of the temperature and collective flow parameters for different hadronic species. The study reveals the presence of a significant collective flow and a well defined temperature in the system thus indicating the formation of a thermally equilibrated hydrodynamic system in p-p collisions at LHC. Moreover, the fits to the available experimental rapidity distributions data of strange hadrons show the effect of almost complete transparency in p-p collisions at LHC. The model incorporates longitudinal as well as a transverse hydrodynamic flow. The contributions from heavier decay resonances have also been taken into account. We have also imposed the criteria of exact strangeness conservation in the system.

WG5: High Multiplicities / 23

Multiplicity dependence of light flavour hadron production at LHC energies in the strangeness canonical suppression picture

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The recently observed phenomenon of enhanced strange particle production in high multiplicity pp collisions at LHC is not yet well understood from a theoretical point of view. While a modelling based on QCD inspired MC models such as PYTHIA, DIPSY or EPOS aims at a microscopic understanding, we present two alternative approaches to study light flavour hadron production as a function of event multiplicity using macroscopic thermal-statistical and Core-Corona models. The strangeness-canonical approach embedded in THERMUS is used for the simultaneous description of hadron-to-pion yield ratios in pp, p-Pb and Pb-Pb collisions and compared to predictions from Core-Corona. The rapidity window dependence of the strangeness correlation volume is addressed and a very good agreement between the data and the models except for the phi-meson is observed.

WG6: Interactions with Nuclei / 24

Color fluctuation effects in hard nucleon and photon collisions with nuclei

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Abstract: We test the hypothesis that configurations of a proton with a large- x parton, $x_p > 0.1$, have a smaller than average size. The QCD Q^2 evolution equations suggest that these small configurations also have a significantly smaller interaction strength, which has observable consequences in collisions with nuclei. We perform a global analysis of jet production data in proton- and deuteron-nucleus collisions at RHIC and the LHC. Using a model which takes a distribution of interaction strengths into account, we quantitatively extract the x_p -dependence of the average interaction strength, $\sigma(x_p)$, over a wide kinematic range. By comparing the RHIC and LHC results, our analysis finds that the interaction strength for small configurations, while suppressed, grows faster with collision energy than does that for average configurations. We check that this energy dependence is consistent with the results of a method which, given $\sigma(x_p)$ at one energy, can be used to quantitatively predict that at another. This finding further suggests that at even lower energies, nucleons with a large- x_p parton should interact much more weakly than those in an average configuration, a phenomenon in line with explanations of the EMC effect for large- x_p quarks in nuclei based on color screening. We also consider color fluctuations in various photon-nucleus processes which can be explored in the ultraperipheral heavy ion collisions at the LHC

WG5: High Multiplicities / 25

Initial state effects and collectivity in p+p and p+A collisions at the LHC

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In this talk I will discuss on the latest developments in the theoretical description of small collision systems at the LHC. In particular I will discuss how our understanding of the initial state geometry and momentum space correlations can help explain the origin of collectivity in small collision systems at the LHC.

WG1: Minimum Bias and Underlying Event / 26

Interplay of underlying event and event shape observables in Z-boson events

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Experimental measurement of observables sensitive to underlying event (UE) has been performed by both ATLAS and CMS experiments at the LHC. However, in the busy LHC environment, these observables receive substantial contribution from extra jets. In this study, we probe if using event shape observables in conjunction with UE observables can help us to disentangle the effect of UE from extra jets.

WG4: Small-x and Diffraction / 27

Looking for BFKL dynamics at the LHC using jet gap jet events

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After recalling briefly the BFKL NLL fits to the HERA forward jet data, we will describe how jet gap jet events at the LHC can be a good observable to look for BFKL resummation effects. We will discuss the full NLL BFKL calculation of such processes

WG5: High Multiplicities / 28

Charged-particle multiplicity dependence of open heavy-flavour production in pp collisions with ALICE at the LHC

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Heavy-flavour production in pp collisions at LHC energies is described by perturbative QCD calculations based on the factorization approach in which the cross-section is obtained as a convolution of a hard process, parton distribution functions and fragmentation functions. The investigation of heavy-flavour production as a function of event properties, like charged-particle multiplicity, can provide further insight into the global features of the collision. This measurement helps also to characterize the particle production mechanism, to assess the interplay between the hard and soft processes and to test models which include multiple parton interactions.

The ALICE experiment studied heavy-flavour production at different collision energies via the hadronic and semi-leptonic decay channels, at central and forward rapidity. Charged-particle multiplicity is

also measured at central and forward rapidity, allowing to study the rapidity range of possible connections of soft and hard processes.

In this contribution, the measurements of open heavy-flavour production as a function of charged-particle multiplicity in pp collisions at ALICE will be discussed. The results will be compared to quarkonium measurements as well as theoretical model calculations.

WG1: Minimum Bias and Underlying Event / 29

J/Psi production in jets at LHCb

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The production of J/ψ mesons in hadron-hadron collisions occurs at the transition between the perturbative and non-perturbative regimes of quantum chromodynamics, resulting in a rich phenomenology that is yet to be fully understood.

LHCb studied the production of J/ψ mesons in jets in the forward region of proton-proton collisions at a center-of-mass energy of 13 TeV. The fraction of the jet transverse momentum carried by the J/ψ meson, $z(J/\psi) \equiv p_T(J/\psi)/p_T(\text{jet})$, is measured using jets with $p_T(\text{jet}) > 20$ GeV in the pseudorapidity range $2.5 < \eta(\text{jet}) < 4.0$. The observed $z(J/\psi)$ distribution for J/ψ mesons produced in b-hadron decays is consistent with expectations. However, the results for prompt J/ψ production do not agree with predictions based on fixed-order non-relativistic QCD. This is the first measurement of the p_T fraction carried by prompt J/ψ mesons in jets at any experiment.

WG6: Interactions with Nuclei / 30

LHCb results on nuclear collisions

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In the last years the LHCb experiment has started to provide novel inputs to heavy ion physics by exploiting some of its unique features. Particle production can be studied in p-p, p-Pb and Pb-Pb collisions at LHC energies for pseudorapidity between 2 and 5, providing measurements which are highly complementary to the other LHC experiments.

The excellent vertexing and particle identification capabilities allow exclusive measurements of open and hidden charm states, including baryons, distinguishing the prompt component from the charm hadrons produced in b decays.

Collisions of LHC beams on fixed targets are also studied using the internal gas target SMOG. Production measurements in this unique kinematic range provide crucial constraints on models of key interest for cosmic ray physics as well as for cold nuclear matter effects. An overview of the LHCb heavy ion program will be given, and selected results will be presented.

WG4: Small-x and Diffraction / 31

Central exclusive production at LHCb

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

WG3: Double Parton Scatterings / 32

DPS studies with open charm hadrons at LHCb

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LHCb observed the associated production of bottomonia and open charm hadrons in pp collisions at centre of mass energies of 7 and 8 TeV is observed. Production cross-sections are measured for $Y(1S)D0$ and $Y(1S)D+$ pairs in the forward region. Measurements of the production of J/ψ mesons accompanied by open charm, and of pairs of open charm hadrons are shown.

WG3: Double Parton Scatterings / 33

Double J/Psi production at LHCb

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The production cross-section of J/ψ pairs in the forward region is measured using a data sample of pp collisions collected by the LHCb experiment at a centre-of-mass energy of 13 TeV. Differential cross-sections are presented as functions of several kinematic variables of the J/ψ pair are measured and compared to theoretical predictions.

WG2: MC Development and Tuning / 34

Soft interactions in Herwig

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We review the current model for soft interactions which is based on multiperipheral particle kinematics in the Monte Carlo event generator Herwig 7. Furthermore we investigate the consequences of additional modifications related to soft physics in pp collisions with respect to hadronic flavour observables.

WG2: MC Development and Tuning / 35

MPI in EPOS

Author: Klaus Werner^{None}

EPOS is a “unified approach” for simulating small and big systems (pp to heavy ions), in all cases implementing initial multiple scatterings and final state interactions, the latter ones being essentially a hydrodynamical evolution of the core part. We report about recent developments of the EPOS approach, aiming to understand the transition from small to big systems.

WG2: MC Development and Tuning / 36

QCD Monte-Carlo model tuning studies with CMS data at 13 TeV

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New CMS PYTHIA 8 event tunes are presented. The new tunes are obtained using minimum bias and underlying event observables using Monte Carlo configurations with consistent parton distribution functions and strong coupling constant values in the matrix element and the parton shower. Validation and performance studies are presented by comparing the predictions of the new tune to various soft- and hard-QCD measurements at 7, 8 and 13 TeV with CMS.

WG2: MC Development and Tuning / 37

CMS underlying event and double parton scattering tunes

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Several new double parton scattering (DPS) tunes are constructed in order to investigate the compatibility between the values of the UE parameters determined from fitting UE observables and the values determined from fitting DPS-sensitive observables. In addition, the predictions of the DPS-based tunes are tested against UE observables at 13 TeV.

WG2: MC Development and Tuning / 38

Tuning of color reconnection models with CMS data at 7 and 13 TeV

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A study of the latest color-reconnection models in QCD is performed with CMS data. The so called MPI-based, QCD-inspired and gluon-move models are studied within Pythia8, and the tuning parameters for the color reconnection and multiple parton interactions are extracted simultaneously from data. The different tunes are compared with top quark distributions.

WG4: Small-x and Diffraction / 39

CT-PPS physics results and prospects

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This talk will discuss recent CT-PPS results concerning exclusive di-lepton production and prospects for future measurements concerning anomalous couplings.

WG4: Small-x and Diffraction / 40

Very forward jet, Mueller Navelet jets and jet gap jet measurements in CMS

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This talk will describe recent results from CMS on very forward jets in CASTOR, jet gap jets and Mueller Navelet jets as a possible sign of BFKL dynamics.

WG3: Double Parton Scatterings / 41

DPS Measurements at CMS

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We present recent results on Double Parton Scattering (DPS) studies using data collected during Run 1 and Run 2 of the LHC with the CMS experiment. Double parton scattering is investigated in several final states including vector bosons and multi-jets. Measurements of observables designed to highlight the DPS contribution are shown and compared to MC predictions from models based on multiple partonic interactions (MPI) phenomenology.

WG1: Minimum Bias and Underlying Event / 42

Minimum Bias and UE measurements at CMS

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We present results on the measurement of the underlying event at 13 TeV using leading tracks, jets, and Drell-Yan processes. This presentation also includes recent results from Minimum Bias measurements with CMS experiment.

WG3: Double Parton Scatterings / 43

Double Parton Scattering with the ATLAS Experiment

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Double Parton Scattering with the ATLAS Experiment
Abstract:

A wide programme of studies of Double Parton Scattering (DPS) processes is performed with the ATLAS detector at LHC. DPS processes are studied not only with charm and beauty hadrons, but also with jets and W bosons in the final state topology. The talk will review the measurements of several properties of DPS processes in these channels performed by the ATLAS detector using data collected during the LHC Run1 campaign.

WG5: High Multiplicities / 44

Multiplicity dependence study of the pseudorapidity density distribution of charged particles in pp collisions with ALICE

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In this contribution, we report on the multiplicity dependence of the pseudorapidity density distribution of charged particles in proton-proton (pp) collisions at $\sqrt{s} = 5.02$ TeV and at 13 TeV with the ALICE experiment. The measurements rely on track segments reconstructed with the Silicon Pixel Detector in the kinematic region $|\eta| < 1.8$. Results are presented for three different event classes: inelastic (INEL), inelastic events with at least one charged particle in the central region $|\eta| < 1.0$ (INEL > 0), and non-single-diffractive (NSD) events for pp collisions at $\sqrt{s} = 5.02$ TeV. The measurements are shown for different multiplicity slices, defined by a forward multiplicity estimator and a central multiplicity estimator, which manifest different physics. To understand better the role of collective effects that have been recently observed in pp collisions, the evolution of the shapes of pseudorapidity density distributions at very high multiplicities is presented for pp collisions at $\sqrt{s} = 13$ TeV using data collected with high-multiplicity triggers. The results are compared to the

predictions from the QCD-inspired Monte Carlo (MC) event generator PYTHIA and to expectations from the hydrodynamically treated MC event generator EPOS-LHC.

WG5: High Multiplicities / 45

New results on multiplicity and event shape dependence of particle production in pp collisions

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Event shape observables are important tools to get an insight into the physics behind collective phenomena in high multiplicity pp collisions at LHC energies. They can be used to disentangle the contributions from hard and soft processes to particle production. We report measurements with the ALICE detector at the LHC of the production of inclusive and identified charged particles as a function of charged particle multiplicity and transverse sphericity in pp collisions at $\sqrt{s} = 13$ TeV. The results include the transverse momentum (p_T) distributions of pions, kaons and protons as well as the $\langle p_T \rangle$ and particle yield ratios. The results are compared to predictions from QCD inspired event generators such as EPOS-LHC, PYTHIA 6 and PYTHIA 8.

WG1: Minimum Bias and Underlying Event / 46

Measurement of the Underlying Event in pp collisions at $\sqrt{s} = 13$ TeV with the ALICE experiment at the LHC

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Large In LHC RUN II, the Large Hadron Collider restarted with a centre-of-mass energy increase of around 60% with respect to the end of the LHC RUN I. At this new energy it is absolutely essential to restudy the general features of the pp interaction, in particular the soft or semi-hard bulk of particles that form the Underlying Event, which is defined to be the complementary activity with respect to the leading interaction.

Measurements of the Underlying Event allows us to access fundamental information on the hadron structure. This has important consequences for lepton and photon isolation, and also for jet calibration.

In order to estimate the contributions to the Underlying Event, we present a characterization of the event properties focusing on the orthogonal plane with respect to the beam direction: the primary charged particle with the highest transverse momentum - defined to be the leading charged particle - is used to give the energy scale of the interaction. Primary charged particle and energy densities are measured in different azimuthal regions with respect to the leading charged particle. Three track p_T cuts are considered: 1, 0.5 and 0.15 GeV/c.

In this talk, the first results on Underlying Event measurement in pp collisions at $\sqrt{s} = 13$ TeV will be presented.

WG6: Interactions with Nuclei / 47**Measurement of open heavy-flavour production in p-Pb collisions with ALICE at the LHC****Author:** Sudipan De¹¹ *Indian Institute of Technology Indore (IITI)***Corresponding Author:** sudipan.de@cern.ch

The ALICE experiment is dedicated to study the properties of the strongly-interacting matter, usually referred to as the Quark-Gluon Plasma (QGP), created in high-energy heavy-ion collisions. Heavy quarks, i.e. charm and beauty, are produced in the initial stages of the collision via hard scattering processes. Thus they probe the full evolution of the system. Measurements in p-Pb collisions help understanding the Cold Nuclear Matter effects (CNM) such as modifications of the parton distribution function (PDF) in nuclei, energy loss and momentum broadening. Moreover, measurements of open heavy-flavour particles production as a function of charged-particle multiplicity in p-Pb collisions can provide information on the dependence of CNM effects on the collision geometry and on the density of final-state particles. Furthermore, the possible presence of collective effects in high-multiplicity p-Pb events could modify the spectra of heavy-flavour hadrons. In addition, these measurements allow us to study the interplay between the hard and soft processes in heavy-flavour production.

In ALICE, open heavy-flavour production is studied through the measurements of the heavy-flavour decay leptons, i.e. electrons and muons at central and forward rapidity respectively, and via the reconstruction of D-meson hadronic decays at central rapidity. In this contribution, recent measurements of open heavy-flavour production from p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV collected during Run I and Run II of the LHC are presented. The focus will be on the measurements of the angular correlations with charged particles, multiplicity dependence of nuclear modification factor and relative yield as a function of multiplicity.

WG5: High Multiplicities / 48**Energy and multiplicity dependence of the strangeness enhancement in pp collisions****Author:** Francesca Bellini¹¹ *CERN***Corresponding Author:** francesca.bellini@cern.ch**Energy and multiplicity dependence of the strangeness enhancement in pp collisions**

The ratio of the p_T -integrated yield of strange and multi-strange particles relative to non-strange hadrons has been measured as a function of the event activity in pp collisions at the LHC, revealing that from low to high multiplicity events, strange hadron production increases smoothly and continuously until it reaches the values measured in Pb-Pb collisions. The trend, more pronounced for multi-strange baryons, is remarkably similar to the one observed in p-Pb collisions, indicating that the phenomenon is related to the final system created in the reaction. The results obtained by ALICE in pp collisions at $\sqrt{s} = 7$ and 13 TeV are presented. The multiplicity-differential measurements at different collision energies allow one to disentangle the energy and multiplicity dependence of the effect. The results are compared to predictions from QCD-inspired Monte Carlo generators commonly employed in high energy physics (PYTHIA, DIPSY, EPOS-LHC) and also discussed within the strangeness-canonical suppression picture. Perspectives for measurements of strangeness production in high multiplicity pp collisions using a large triggered sample of LHC Run II data will be presented.

WG6: Interactions with Nuclei / 49**Recent results from femtoscopic studies with ALICE at LHC****Author:** Ashutosh Kumar Pandey¹¹ *IIT- Indian Institute of Technology (IN)***Corresponding Author:** ashutosh.kumar.pandey@cern.ch

We present the review of recent results of femtoscopic studies performed by ALICE experiment at the LHC in heavy ion and pp collisions. The measurements include the correlations between the identical and non-identical pairs of mesons and baryons. These correlations which arise from quantum statistics and final-state interactions among the produced particles, probe the space-time characteristics of particle production. The measurements involving pions, kaons and protons probe its hydrodynamic evolution. Results for heavy-ion collisions are consistent with the presence of a flowing medium which can be seen as manifestation of the collective behavior of the produced particles. The measured three-dimensional radii in heavy-ion collisions scales with event multiplicity what provides strict constraints on the dynamical models. The trends observed in high-multiplicity pp collisions show similarities to heavy-ion collisions.

WG5: High Multiplicities / 51**Energy and multiplicity dependence of identified charged particle production in pp collisions****Author:** Natasha Sharma¹¹ *Panjab University (IN)***Corresponding Author:** natasha.sharma@cern.ch

In recent years, the ALICE experiment has collected data in proton-proton collisions at various centre-of-mass energies. In addition to providing a baseline for heavy-ion collisions, these data provide information on the particle production in high energy collisions through the study of energy dependence of various observables. With large statistics data samples collected in pp at $\sqrt{s} = 7$ and 13 TeV, it is possible to investigate the multiplicity dependence of observables. Hence one can test the behaviour of observables related to possible quark-gluon plasma formation in high multiplicity pp collisions.

We report on the energy dependence of identified particles (such as π^\pm , K^\pm , p, \bar{p} , light nuclei and anti-nuclei) production in pp collisions. The multiplicity dependence is studied for pp collisions at 7 TeV and 13 TeV. The data are compared with available QCD inspired models.

WG3: Double Parton Scatterings / 53**Production of two pairs of J/ψ mesons and simultaneous production of D and B mesons in the context of double parton scattering****Authors:** Antoni Szczurek¹; Anna Cisek²; Wolfgang Schaefer³

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Phenomena of multiple-parton interaction (MPI) have become very essential for precise description of high-energy proton-proton collisions in the ongoing LHC era.

Some time ago we have proposed and discussed double open charm meson production $pp \rightarrow DD X$ as a potentially one of the best reaction to study hard double-parton scattering effects at the LHC.

This conclusion was further confirmed by the LHCb collaboration that has reported surprisingly large cross sections for DD meson-meson pair production in pp -scattering at 7 TeV.

Here we discuss production of two pairs of J/ψ quarkonia in the context of recent results obtained at the LHC at large and intermediate p_t .

The leading-order $\mathcal{O}(\alpha_s^4)$, called here also box, contribution is calculated in both collinear and the k_t -factorization approach with the KMR unintegrated gluon distributions.

We include also two-gluon exchange (between two $c\bar{c}$ intermediate pairs) contribution which is of the order of $\mathcal{O}(\alpha_s^6)$, in the moment only in the collinear approximation.

We calculate cross sections for $pp \rightarrow \chi_c(J_1)\chi_c(J_2)$.

A feed-down from double χ_c single-parton-scattering production is estimated for the first time.

The double parton scattering is calculated using an educated parametrization of single J/ψ differential distributions in rapidity and transverse momentum at the LHC energies.

Many differential distributions are calculated.

Results of our calculations are compared with very recent ATLAS data.

We find that the two-gluon exchange mechanism and the double feed down lead to very similar (in shape) distributions in rapidity distance between the J/ψ mesons.

Much larger cross sections are obtained in the k_t -factorization approach.

Including the mechanisms, some of them for a first time, leaves much less room for the double parton scattering contribution which cannot be calculated from first principle.

The σ_{eff} parameter for DPS needed to describe the ATLAS data is therefore much larger than from previous studies of double quarkonium production, where a smaller number of mechanisms was included.

In addition here, we present results of phenomenological studies of DPS effects in the case of associated open charm and bottom

$pp \rightarrow D^0 B^+ X$ as well as double open bottom

$pp \rightarrow B^+ B^+ X$ production. In particular, we will show

theoretical predictions of integrated and differential cross sections for different energies that could help to conclude whether and how the DPS effects for these two cases can be observed experimentally by the LHCb/CMS collaborations.

Single and double scattering production of four leptons in lead-lead UPC

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We will report on our results for electromagnetic (two-photon) single and double scattering production of two positron-electron and muon pairs in ultraperipheral ultrarelativistic two lead ions collisions. We consider double-scattering contribution obtaining measurable cross section. We take into account realistic cuts on electron/positron or muon (pseudo)rapidities and transverse momenta for the ALICE, ATLAS or CMS experiment. Total and differential cross sections will be presented. We will show and compare also energy dependence of the cross sections for one- and two-pair production. We will present, for a first time, results for direct $\gamma\gamma$ production of four leptons in one scattering. We will study an unexplored process $\gamma\gamma \rightarrow l^+l^-l^+l^-$.

The nuclear $\text{PbPb} \rightarrow \text{PbPb}4\mu$ and $\text{PbPb} \rightarrow \text{PbPb}4e$ cross sections are calculated in the equivalent photon approximation. In our calculations we use the photon flux taking into account realistic nuclear charge form factor which is a Fourier transform of the realistic charge distribution.

We demonstrate explicitly that the cross section for the single-scattering mechanism is considerably smaller than the cross section for the double-scattering mechanism. This shows that the DS mechanism is sufficient for detailed studies and planning experiments.

This talk will be based mainly on our analyses which were presented in Ref. [1] and [2].

References:

- [1] M. Klusek-Gawenda and A. Szczurek,
Double scattering production of two positron–electron pairs in ultraperipheral heavy-ion collisions,
Phys. Lett. **B763** (2016) 416-421,
[2] A. van Hameren, M. Klusek-Gawenda and A. Szczurek,
Single- and double-scattering production of four muons in ultraperipheral PbPb collisions at the
Large Hadron Collider,
accepted for publication in Physics Letters B, e-Print: arXiv:1708.07742 [hep-ph].

Annotation: I am mother of a twelve-month-old baby therefore I would like to request to give a talk by skype/video.

WG4: Small-x and Diffraction / 56

An analytical approach to Froissart bound in a proton structure function

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We review the analytical description of Froissart saturation condition in a transverse-momentum-dependent parton distribution function of a self-similarity based proton structure function $F_2(x, Q^2)$ at small x . Saturating the Froissart bound refers to an energy dependence of the total cross-section rising no more rapidly than $\ln^2 s$, where s is the square of cms energy. Our study shows that such a slow growth is not compatible with self-similarity based proton structure function which has a power law growth in $1/x$.

WG2: MC Development and Tuning / 58**Sartre, a dipole model generator for the Electron Ion Collider****Author:** Tobias Toll^{None}**Corresponding Author:** ttoll@bnl.gov

I will present the Sartre event generator. It is using the bSat Dipole Model at its core and can simulate exclusive diffraction in ep and eA as well as ultra peripheral collisions in pp, pA, and AA collisions. It has a mechanism for varying the nuclear configurations thereby providing both coherent and incoherent cross-sections for photon-nucleus interactions, and in the latter case uses FLUKA to simulate nuclear breakup.

As new combined data has been made available from the HERA II run, the values of the parameters of the bSat dipole model can be improved. I will also discuss the ongoing work on making a new fit of the dipole model parameters to the latest combined HERA I&II data for inclusive DIS and inclusive diffraction. The new data provides an opportunity to restrict the proton's gluonic size and shape in an unprecedented manner which we aim to take advantage of, aiming to make a consistent fit for inclusive DIS, inclusive diffraction and exclusive diffraction. Also, we investigate a consistent way to handle light quark flavours in the fit, which are strongly related to confinement effects important for large dipoles.

WG5: High Multiplicities / 59**Multiplicity Dependence of Non-extensive Parameters for Strange and Multi-Strange Particles in Proton-Proton Collisions at $\sqrt{s} = 7$ TeV at the LHC****Authors:** Arvind Khuntia¹; Sushanta Tripathy¹; Raghunath Sahoo¹; Jean Cleymans²¹ *Indian Institute of Technology Indore (IN)*² *Department of Physics***Corresponding Authors:** arvind.khuntia@cern.ch, raghunath.sahoo@cern.ch, jean.cleymans@cern.ch, sushanta.tripathy@cern.ch

High-energy heavy-ion collisions at RHIC and LHC provide a unique opportunity to study nuclear matter under extreme conditions i.e. at high temperature and/or energy density. Due to the high multiplicities produced in $p + p$ collisions, one can use the statistical models to describe the particle production mechanism. As thermodynamically consistent Tsallis statistics has been successful in describing the transverse momentum (p_T) spectra of identified particles, we use this distribution to fit the entire p_T spectra and study the Tsallis parameters as a function of multiplicity as well as mass for the strange (K_S^0 , $\Lambda + \bar{\Lambda}$) and multi-strange particles ($\Xi^- + \bar{\Xi}^+$, $\Omega^- + \bar{\Omega}^+$) in $p + p$ collisions at $\sqrt{s} = 7$ TeV. The extracted non-extensive parameter decreases towards 1 for high multiplicity event classes except K_S^0 , shows the tendency of the produced system to equilibrate with higher multiplicities. Similarly T shows a systematic increase with multiplicity, the heaviest baryons showing the steepest increase. This is an indication of a mass hierarchy in particle freeze-out. The radius has a tendency to remain constant at high multiplicities. These changes have implications for the kinetic freeze-out conditions where the heavy multi-strange hadrons are seen to have an earlier kinetic freeze-out, meaning they come from a smaller volume at a higher temperature. These results show that the Tsallis distribution is an excellent tool to analyze high-energy $p + p$ collisions

WG1: Minimum Bias and Underlying Event / 60

Hadronic Event Shape Variables in pp Collisions at $\sqrt{s} = 13$ TeV

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We present results on measurements of characteristics of events with jets and event shape measurements by CMS using data from pp collisions. The measurements are compared to theoretical predictions from different models of parton shower and hadronization.

WG6: Interactions with Nuclei / 61

Results of Ultrapерipheral heavy ion collisions with the CMS experiment

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Ultrapерipheral collisions (UPCs) of heavy ions or hadrons involve long range electromagnetic interactions at impact parameters larger than the sum of their radii where hadronic interactions are largely suppressed and they interact electromagnetically via emission of quasi-real photons. Photoproduction of heavy vector mesons (J/psi, Upsilon) provides direct information on the gluon distribution functions in the nucleon/nucleus at very low values of Bjorken-x. The measured coherent J/psi photoproduction cross section in ultraperipheral Pb-Pb collisions using 2011 PbPb data and Upsilon photoproduction in ultraperipheral p-Pb collisions using 2013 data will be presented. Two photon processes in UPC collisions provide a wide range of opportunities from testing fundamental Quantum Electro Dynamics (QED) to searches for physics beyond the Standard Model (SM). The prospects of photon-induced measurements with heavy ions using Run 2 data at the LHC will be also discussed.

WG4: Small-x and Diffraction / 62

Diffraction results from CMS and TOTEM

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This talk will cover TOTEM results on soft diffraction (total, elastic and inelastic cross sections) as well as the CMS/TOTEM results.

WG6: Interactions with Nuclei / 64

System size dependence of particle production in pp, p-Pb and Pb-Pb collisions at 5.02 TeV

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The ALICE collaboration has measured the production of light-flavour hadrons in pp, p-Pb and Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV over a wide range of transverse momentum (p_T). The results on π , K, p, K^{*0} and ϕ p_T spectra, ratios of the p_T -integrated yields and mean transverse momentum will be presented for the three colliding systems at the same energy ($\sqrt{s_{NN}} = 5.02$ TeV), and compared as a function of average charged particle multiplicity measured at mid-rapidity. It will be shown that the production of these particles follows a continuous trend as a function of multiplicity across the three systems. Identified particle ratios provide information on the composition and the thermal properties of the medium. The measurement of short-lived hadronic resonance production and their ratio to stable hadron species, such as ϕ/K and K^{*0}/K , is used to infer information on the hadronic phase.

Parton energy loss is investigated by determining the nuclear modification factor (R_{AA}). The production of light-flavour hadrons in the most central Pb-Pb collisions relative to pp collisions is found to be strongly suppressed at high p_T (> 8 GeV/c), whereas in p-Pb collisions the nuclear modification factors are consistent with unity. This indicates that the strong suppression of high- p_T hadrons measured in central Pb-Pb collisions is not due to an initial state effect but instead to the energy loss of partons traversing a hot and dense QCD medium. A similar suppression is observed for all the measured light-flavour hadrons at $p_T > 8$ GeV/c. This suggests that the partonic energy loss in the medium for light quark flavors (u, d, s) is independent of flavour.

WG5: High Multiplicities / 65

Two-particle correlation and flow of identified hadrons in small systems at LHC energies

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Recent measurements in proton-proton (pp) and proton-nucleus (pA) collisions at LHC energies show that the charged particle multiplicity density is comparable to that produced in nuclear collisions at lower energies. The long-range “ridge” structures observed in high multiplicity pp and p-Pb collisions resemble those seen in Pb-Pb collisions. The “ridge” structure in Pb-Pb collisions suggests collective bulk behavior and the corresponding observation in high multiplicity pp and p-Pb collisions indicates a possible connection with multiple partonic interactions.

In this talk, a comprehensive study of long-range correlations in pp and p-Pb and elliptic flow of identified hadrons in p-Pb collisions at LHC energies will be presented. The results will also be compared with corresponding measurements from Pb-Pb collisions.

WG1: Minimum Bias and Underlying Event / 66

Scaling properties of the underlying event in high energy pp collisions

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We study ATLAS results on underlying event in pp collisions at $\sqrt{s} = 0.9, 7$ and $13\sqrt{s}$, TeV. We show that the center-of-mass energy dependences of the charged-particle production sensitive to the underlying event (transverse region) and to the hardest partonic interaction (towards and away regions) in pp collisions can be both understood in terms of the change of the inclusive average multiplicity. Within uncertainties, the corresponding particle production as a function of the leading charged particle shows no significant \sqrt{s} -dependence for the three regions once they are scaled according to the relative change in multiplicity ($|\eta| < 2.5, p_T > 0.5\sqrt{s}$, GeV/c). The scaling properties reported here are well reproduced by PYTHIA 8.212 tune Monash 2013 and suggest an universality of the underlying event in hadronic interactions at high \sqrt{s} . Based on the simulations, we observed that the same scaling properties are also present in the average number of multi-partonic interactions as a function of the leading charged particle. Moreover, the multiplicity distributions associated to the underlying event exhibit a KNO scaling. We also study the pseudorapidity dependence of the UE-related quantities and the source of the breaking of the scaling with the inclusive charged particle multiplicity which was reported by ALICE.

WG6: Interactions with Nuclei / 67

System size dependence of high p_T hadron production at RHIC-PHENIX

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The measurements of high p_T hadron production is an excellent tool to study the parton energy loss in the Quark Gluon Plasma (QGP). The experimental observables of R_{AA} focus on the inclusive suppression, while the high p_T v_n measurements are sensitive to the path-length dependence of the energy loss.

The large suppression ($R_{AA} < 1$) and the positive v_2 were first observed in Au+Au collisions and they largely contribute to the evidence of forming a hot and dense medium in heavy ion collisions. The more precise measurements could provide us more constraints on the understanding of energy loss mechanism in these collision systems.

The measurements of the flow-like behavior in the small systems could result in the creation of a small QGP-like medium in highly asymmetric collision systems. However, there is no strong evidence of the jet suppression presented from these systems.

In this talk, we present the systematic study of the high p_T hadron v_n and R_{AA} in small and large collision systems measured by the PHENIX, and discuss the tendency with centrality classes.

WG2: MC Development and Tuning / 68

An approach to test the core-corona model using multiplicity dependent particle production at LHC energies

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The core-corona picture implemented in the EPOS³ model has successfully described the multiplicity dependence of particle production in proton–proton (pp) and proton–nucleus collisions at LHC energies.

The inclusion of viscous hydrodynamics plays a key role in describing the observed features of data. It suggests an interpretation of new phenomena assuming the formation of a small drop of the Quark-Gluon Plasma.

However, initial state effects produce similar signals. Therefore, novel ideas are of crucial importance in order to make a comprehensive comparison between models and data.

In this regard, we propose a strategy in order to enhance or suppress the effects arising from the core component of the EPOS³ model using measurable quantities. In doing so, based on our earlier studies, we investigate

the simulated sample differentially as a function of event charged-particle multiplicity and the transverse momentum (p_T) of the leading jet (p_T^{jet}) reconstructed at mid-pseudorapidity ($|\eta| < 1$).

The baryon-to-meson and hyperon-to-pion particle ratios as well as the average p_T are determined as a function of multiplicity and p_T^{jet} in inelastic pp collisions at $\sqrt{s} = 7\sqrt{2}$ TeV.

The results suggest sizable effects that could be compared to experimental data.

WG6: Interactions with Nuclei / 69

Measurement of Azimuthal Anisotropy of Hadrons in Au+Au Collisions at RHIC

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The aim of the heavy-ion experiments at RHIC is to study the QCD matter at very high temperature and/or at high density by colliding nuclei at ultra-relativistic speeds.

Using the information carried by freely streaming final-state particles as probes, we try to understand the properties of the medium created in these collisions. An extensively studied subject is azimuthal anisotropy or elliptic flow (v_2), the collective anisotropic expansion of the medium, originating from the initial spatial anisotropy of the colliding nucleons, and driven by the strong interaction among particles produced in the collision. Due to low hadronic interaction cross-section and early freeze-out, v_2 of (multi)strange hadrons are considered as a better probe of collectivity from the early stage. On the other hand, due to the large mass, heavy charm quarks can only be produced during initial hard scattering and their thermalization time is expected to be delayed by a factor $m_Q/T \sim 5$ fm/c for charm quark (m_Q is the mass of quarks and T is the medium temperature). Hence, v_2 of charm quark carrying hadrons can be used to measure the degree of thermalization of the QCD medium. In this talk, I will discuss recent v_2 results from the STAR experiment at RHIC. We will present v_2 of light (u, d), strange (s) and charm (c) quark carrying hadrons as a function of transverse momentum in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Measurements will be compared with available theoretical models to extract viscous and diffusion coefficient of the produced medium. Energy dependence of light and (multi)strange hadrons v_2 will be shown and its physics implication will be discussed.

WG6: Interactions with Nuclei / 70

Particle production in heavy-ion collisions at RHIC

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The beam-energy scan at RHIC aims to discover whether a critical point exists in the phase diagram of QCD. We will report on the most comprehensive measurement of single-particle spectra for a multitude of hadrons from the first run, taken with the STAR experiment. From these measurements we will infer the kinetic and chemical freeze-out temperatures and the baryon chemical potential as functions of beam energy and centrality. The freeze-out dynamics of the system formed in heavy-ion collisions will be discussed in detail. The results provide an opportunity for the beam-energy scan program at RHIC to enlarge the (T, μ_B) region of the phase diagram to search for the QCD critical point.

WG4: Small-x and Diffraction / 71

Studies of Diffractive Events with H1 and ZEUS Detectors at HERA

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Studies of diffractive events at H1 and ZEUS detectors at HERA are presented. These studies include: Production of exclusive dijets in diffractive deep inelastic scattering (DIS); Exclusive ρ^0 meson photoproduction with a leading neutron; Measurement of D^* meson production in diffractive deep inelastic scattering; Diffractive photoproduction of isolated photons; Measurement of the cross-sections and their ratios for electroproduction of $\psi(2S)$ and $J/\psi(1S)$. The data used for first three studies are taken from HERA-II, however those used for last two are taken from both HERA-I and HERA-II running periods. The overall kinematic range covered with these measurements is $2 < Q^2 < 180$ GeV² (photon virtuality) for diffractive DIS and $Q^2 < 1$ GeV² for diffractive photoproduction. The total energy of the photon proton system (W) covered in the presented studies extends from 30 GeV to 250 GeV and with an electron-proton centre of mass energy, $s = \sqrt{319}$ GeV. The results are compared to predictions from models based on different assumptions about the nature of the diffractive exchange.

WG4: Small-x and Diffraction / 72

Low-x and diffraction measurements at RHIC

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RHIC can probe low-x partons in nuclei in p/d+A collisions at forward rapidities, where non-linear QCD effects are expected to set in. So far no clear experimental observation of the onset of gluon saturation has been made. Di-hadron/jet correlations and ratios of hadrons yields in p+p and p/d+A collisions at forward rapidities can be linked to modifications of nuclear parton distributions arising from gluon saturation or gluon shadowing. Furthermore, the long-range ridge-like structure in the di-hadron correlations in p/d+A collisions has also been proposed

to be driven by initial state effects like gluon saturation. Measurements of di-hadron correlations in $p/d/{}^3\text{He}+\text{Au}$ collisions at $\sqrt{s_{NN}} = 200$ GeV and comparisons with model calculations such as IP-Glasma+Hydrodynamics can help us to understand the relative contributions to the observed ridge-like structure from initial and final state effects.

Central Exclusive Production (CEP) processes with tagged forward protons in $p+p$ collisions are being studied at RHIC to search for gluonic bound states, i.e. glueballs. Existence of glueball is allowed in pure gauge QCD and lattice calculations have predicted the lowest-lying states in the mass range of 1500-1700 MeV/c^2 . Since no glueball state has been unambiguously established to date, it is very interesting to study the production of scalar glueball states like $f_0(1500)$ and $f_0(1710)$ in CEP in Double Pomeron Exchange processes, which are being measured at STAR through the diffraction physics program.

This talk will present the recent results and status of the low- x and diffraction physics programs at RHIC. Both STAR and sPHENIX are planning for upgrades at forward rapidities beyond 2020+ to bridge to a future Electron Ion Collider (EIC). The physics program of these upgrades will be discussed.

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MC Tutorial - Part I

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Monte Carlo Tutorial - Part I

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MC Tutorial - Part II

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Monte Carlo Tutorial - Part II

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Conclusions / Highlights / Discussion

The conveners of the working groups give a short (5') presentation mentioning the highlights, the controversial issues and the plans for the future, in the light of triggering a discussion which will be useful for the organisation of the next MPI@LHC edition

WG5: High Multiplicities / 76**Collectivity from interference****Authors:** Boris Blok¹; Urs Wiedemann²; Mark Strikman³; Christian D. Jäkel^{None}¹ *Physics Department*² *CERN*³ *Pennsylvania State University (US)***Corresponding Authors:** blok@physics.technion.ac.il, urs.wiedemann@cern.ch, mark.strikman@cern.ch

In hadronic collisions, interference between different production channels affects momentum distributions of multi-particle final states. As this QCD interference does not depend on the strong coupling constant α_s , it is part of the no-interaction baseline that needs to be controlled prior to searching for other manifestations of collective dynamics, e.g., in the analysis of azimuthal anisotropy coefficients v_n at the LHC. Here, we introduce a model that is based on the QCD theory of multi-parton interactions and that allows one to study interference effects in the production of m particles in hadronic collisions with N parton-parton interactions (\hat{N} sources). In an expansion in powers of $1/(N_c^2 - 1)$ and to leading order in the number of sources N , we calculate interference effects in the m -particle spectra and we determine from them the second and fourth order cumulant momentum anisotropies $v_n\{2\}$ and $v_n\{4\}$. Without invoking any azimuthal asymmetry and any density dependent non-linear dynamics in the incoming state, and without invoking any interaction in the final state, we find that QCD interference alone can give rise to values for $v_n\{2\}$ and $v_n\{4\}$ even, that persist unattenuated for increasing number of sources, that may increase with increasing multiplicity and that agree with measurements in proton-proton (pp) collisions in terms of the order of magnitude of the signal and the approximate shape of the transverse momentum dependence. We further find that the non-abelian features of QCD interference can give rise to odd harmonic anisotropies. These findings indicate that the no-interaction baseline including QCD interference effects can make a sizeable if not dominant contribution to the measured v_n coefficients in pp collisions. Prospects for analyzing QCD interference contributions further and their possible relevance for proton-nucleus and nucleus-nucleus collisions are discussed shortly.

WG3: Double Parton Scatterings / 77**Review of DPS theory results from 2017****Author:** Jonathan Richard Gaunt¹¹ *CERN***Corresponding Author:** jonathan.richard.gaunt@cern.ch

This talk provides a review of the latest results on the theory of Double Parton Scattering

WG4: Small-x and Diffraction / 78**The Electron-Ion Collider project**

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In this talk, we will describe the Electron-Ion Collider project and the physics that can be done.

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Welcome by Convener

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About workshop

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Inaugural

Introduction/Welcome / 82

Information about initial logistics

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follow up of the MC Tutorial - Students' talk