12th International workshop on Multiple Partonic Interactions at the LHC

Monday, 11 October 2021 - Friday, 15 October 2021

LIP Lisbon

Book of Abstracts

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WG4: small-x and diffraction / 3

Elastic photon-initiated production at the LHC: the role of hadron-hadron interactions

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We discuss the role of additional hadron-hadron interactions in elastic photon-initiated production at the LHC, both in proton and heavy ion collisions. We in particular assess different sources of uncertainty associated with these cross sections, and compare with other calculations in the literature. A key result of our analysis is that the uncertainty associated with the survival factor is small, and it is only by taking very extreme and rather unphysical variations in the modelling of the survival factor that significant differences in the predicted cross sections. This underlines the basic, rather model independent, point that a significant fraction of elastic photon-initatied scattering occurs for hadron-hadron impact parameters that are simply outside the range of QCD interactions, and hence this sets a lower bound on the survival factor in any physically reasonable approach.

WG3 / 4

Event-shapes and the presence of jets in e+e-and pp collisions (15+3)

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Event-shape observables such as transverse sphericity are widely being used by the particle and nuclear physics community to characterize events and study the underlying physics mechanisms.
In earlier studies these observables proved useful in e+e- collisions to discriminate between di-jet and multi-jet topologies, and more recently were exploited in pp collisions.
However, by using events produced with the PYTHIA event generator, we have found that in pp collisions the correlation between event-shape observables and jets is far weaker than is the case in e+e- collisions. Rather, there is an indication that event-shapes in pp collisions are sensitive to the amount of multi-parton interactions, which motivates further investigation of the use of these observables in a new way.
In this talk we present results that support our claim that event-shapes in pp collisions are sensitive to fundamentally different event characteristics and physics mechanisms compared to the same observables in e+e- collisions, which is contrary to what the community has claimed thus far.

WG4: small-x and diffraction / 5

The Electron Ion Collider and gluon imaging using azimuthal correlations at the EIC

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We calculate azimuthal correlations between the exclusively produced virtual photon or vector meson and the scattered electron in Deep Inelastic Scattering processes at the future Electron-Ion Collider (EIC). We identify "kinematical" and "intrinsic" contributions to these correlations. Performing explicit calculations within the Color Glass Condensate framework we show that the correlations are sensitive to the non-trivial spatial correlations in the gluon distribution of the target, and that significant azimuthal modulations could be measured at the future EIC.

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LHCb measurement of double parton scattering in pPb collsions

Authors: Stefania Ricciardi[1]; LHCb Collaboration[None]

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Within the pPb data sample collected by the LHCb detector at sqrt(s_NN) = 8.16 TeV, a rich set of open charm hadrons is observed with abundant statistics. Thanks to the LHCb forward acceptance and the excellent performance in particle reconstruction and identification, these charm states are studied down to zero pT. In this talk, we present latest result of double charm meson production in pPb collisions by LHCb, measured for the first time in heavy ion collisions. Comparisons between Pythia predictions and data are also made.

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Forward dijet production at the EIC: beyond the TMD factorization

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The measurement of azimuthal correlations in the production of forward dijet in deep inelastic scattering provides a unique channel to access the small-x regime of the Weizsäcker-Williams gluon TMD. Its study could potentially provide signatures of gluon saturation at the future Electron-Ion Collider.

While the TMD factorization for semi-inclusive dijet production is expected to hold in the exact back-to-back kinematics, there are important kinematic (perturbative power) and genuine saturation contributions that must be resummed for more controlled phenomenological predictions. The latter contributions account for higher physical degrees of freedom, beyond the TMD distributions, inside hadronic matter. In this talk, I will compare the results of the TMD and the improved TMD factorization framework to those in the CGC EFT, and report on the expected size of kinematic and genuine saturation corrections at different kinematics accessible at the EIC [1]. If time allows, I will discuss recent progress towards the computation of dijet production at the next-to-leading order in the CGC EFT [2].

References:

[1] The importance of kinematic twists and genuine saturation effects in dijet production at the Electron-Ion Collider. R. Boussarie, F. Salazar, H. Mäntysaari, and B. Schenke.

[2] Dijet impact factor in DIS at next-to-leading order in the Color Glass Condensate. P. Caucal, F. Salazar, and R. Venugopalan.

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Study of parton correlations via double parton scatterings in associated quarkonium production in high energy accelerator experiments

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Quarkonium production in proton-proton and proton-antiproton collisions provides interesting means to study the parton content and their correlations in the proton. Recent experimental LHC and Tevatron data of J/psi + Z, J/psi + W and J/psi + J/psi production suggest the relevance of double parton scatterings (DPSs) as opposed to single parton scatterings (SPSs). In this talk, we review the corresponding SPS contributions and discuss upper limits set up by quark-hadron duality. These allow us to perform an improved extraction of the DPS yields whose we discuss the implications.

WG2: Double Parton Scattering / 9

Double-parton scattering studies using gauge bosons and jets at CMS

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A summary of recent results from double-parton scattering studies at CMS will be presented.

WG4: small-x and diffraction / 12

Accessing the proton UGD via exclusive polarized rho-meson leptoproduction at HERA and the EIC

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We study the exclusive polarized leptoproduction of ρ-mesons within the framework of high-energy factorization. Cross sections for longitudinally and transversally polarized mesons are presented. We employ a wide variety of unintegrated gluon distributions available in the literature and compare to HERA data. The resulting cross sections strongly depend on the choice of unintegrated gluon distribution. We also present predictions for the proton target in the kinematics of the Brookhaven EIC.

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Importance of jet fragmentation properties to study double parton scattering

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The fragmentation properties of the quark-initiated jets are significantly different from the gluon-initiated jets. In the present study, the fragmentation properties of jets are explored to check their sensitivity toward double parton scattering. The jets produced in the double parton scattering are observed to be dominated by the ones initiated by gluons, whereas the quark-initiated jets dominate amongst the jets produced by single parton scattering. The discrimination based on fragmentation properties is used to suppress the background from single parton scattering and is observed to be an important tool for the study of double parton scattering.

WG3 / 15

Leptons from HF decays : measurements and inferences towards small systems (15+3)

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Briefly after the Big Bang, the early universe was in a high temperature and high density environment. In order to recreate this state of matter in the laboratory, mini bangs are created by colliding heavy ions at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and subsequently at the Large Hadron Collider (LHC) at CERN. In this talk I shall be covering on the selected results from LHC and RHIC. I shall be covering spectra and correlations (flow) and also nuclear modification factor. I shall be discussing quarkonia flow in further detail. Due to the larger mass of the bottomonium states compared to the charmonium ones,the measurement of bottomonia production in proton-nucleus collisions allows a study of CNM effects in a different kinematic regime, therefore complementing the J/Psi studies[1]. For smaller systems like p+A and p+p we have less deeply bound bottomonia states and thus a comparatively larger chance to escape. This means that more states become measurable, which is a positive feature. On the other hand,it also means that the escape mechanism which underlies the anisotropic flow of bottomonia may become largely ineffective, in particular for the Upsilon(1S). Accordingly,the measurement of a sizable flow

for Upsilon(1S) in small systems[2] would probably hint at the importance of initial-state correlations. Hence understanding small systems becomes very important and such studies will be also stressed and presented including the opportunities which will be possible in LHC Run-3 small system data-sets.
[1] D. Das and N. Dutta, Int. J. Mod. Phys. A 33, no. 16, 1850092 (2018)
[2] D.Das , Nucl.Phys.A 1007 (2021) 122132

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Sum rules for triple parton distribution function

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Recent measurements of the triple J/psi production performed by the CMS collaboration suggest non-negligible contribution from a triple parton scattering (TPS). Therefore, the result of the CSM collaboration can be seen as a first experimental observation of a TPS process. Unfortunately, due to the absence of experimental fits, triple parton distribution functions (tPDFs), needed for the theoretical computation of TPS cross sections, remain unknown. Therefore, in phenomenological studies of the TPS phenomenon one still has to rely on certain model dependent assumptions about the shape of tPDFs and their relation to standard single parton distribution functions.

In this talk I will discuss how one can extend sum rules, previously proposed by Gaunt and Stirling for the double parton distribution functions, to the case of tPDFs and how one can use PYTHIA8 code to construct tPDFs which will approximately obey such sum rules.

WG4: small-x and diffraction / **18**

Small x gluon PDF from LHCb exclusive J/psi data

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The exclusive J/psi production process within a 'tamed'collinear factorisation approach to NLO is described, giving a stable and reliable theoretical prediction owing to the resummation of a class of large logarithms and implementation of a crucial low Q_0 subtraction. A comparison with data from HERA and LHCb is made, before an extraction of a low x ~ 3*10^{-6} and low scale mu^2 ~ 2.4 GeV^2 gluon PDF is obtained via profiling of global PDF sets. The significance of this result for low x global gluon PDF fits is quantified.

WG5: Heavy ions / **19**

Two-particle correlations triggered with strange hadrons in pp collisions at 13 TeV measured with ALICE

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Angular correlations between particles can be utilised to study soft fragmentation and production processes as well as the role of multiple parton interactions. Moreover, a study of the multiplicity dependence can further differentiate between the connection of bulk particles and strangeness production in a more dense environment and the potential role of collective effects.
In this talk, we present results on the two-particle correlation studies in pp collisions at 13 TeV measured with ALICE where strange hadrons (K^0_S,Λ and Ξ) are used as trigger particles.
The comparison of the correlation functions of the Ξ hyperon associated with different strange and non-strange mesons and baryons with different models such as PYTHIA8 or EPOS provides an insight into the strangeness production mechanism. The ratios of the per-trigger yields from K^0_S-h and Λ-h to the yields extracted from the h-h correlation function are sensitive to the difference between quark and gluon jets hadronisation mechanism. The multiplicity and $p_\mathrm{T}^\mathrm{trigg}$ dependence of the per-trigger yields and balanced yields will be shown.

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irst observation of triple-J/psi production in pp collisions, and constraints on double and triple parton scatterings

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The first observation of the combined production of three J/ψ mesons in proton-proton collisions at a center-of-mass energy of 13 TeV is reported. The analysis is based on a data sample recorded by the CMS experiment at the CERN LHC corresponding to an integrated luminosity of $133\,\mathrm{fb}^{-1}$. The search for triple-J/ψ production is performed in final states with three $\mu^+\mu^-$ pairs that pass fiducial kinematic criteria chosen so as to select high-p_T J/ψ mesons produced at midrapidity. The $\mathrm{pp} \to \mathrm{J}/\psi\,\mathrm{J}/\psi\,\mathrm{J}/\psi\,\mathrm{X}$ process is observed with a significance in excess of five standard deviations. The fiducial cross section for this process is found to be $\sigma(\mathrm{pp} \to \mathrm{J}/\psi\,\mathrm{J}/\psi\,\mathrm{J}/\psi\,\mathrm{X}) = 272^{+141}_{-104}(\mathrm{stat}) \pm 17(\mathrm{syst})\,\mathrm{fb}$. The result is compared to theoretical expectations for the production of three J/ψ mesons in single (SPS), double- (DPS), and triple- (TPS) parton scattering processes. Under the most economical assumption of factorization of multiple hard scattering probabilities in terms of SPS cross sections, the measured final state is found to be dominated by DPS and TPS contributions. A value of the associated DPS effective cross section parameter of $\sigma_{\mathrm{eff,DPS}} = 2.7^{+1.4}_{-1.0}(\mathrm{exp})^{+1.5}_{-1.0}(\mathrm{theo})\,\mathrm{mb}$, related to the transverse distribution of partons in the proton, is derived.

WG4: small-x and diffraction / 21

Measurement of lepton-jet correlation in deep-inelastic scattering with the H1 detector using machine learning for unfolding

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The first measurement of lepton-jet momentum imbalance and azimuthal correlation in lepton-proton scattering at high momentum transfer is presented. These data, taken with the H1 detector at HERA, are corrected for detector effects using an unbinned machine learning algorithm (OmniFold), which considers eight observables simultaneously in this first application. The unfolded cross sections are compared to calculations performed within the context of collinear or transverse-momentum-dependent (TMD) factorization in Quantum Chromodynamics (QCD) as well as Monte Carlo event generators. The measurement probes a wide range of QCD phenomena, including TMD parton distribution functions and their evolution with energy in so far unexplored kinematic regions.

arxiv:2108.12376, submitted to PRL

WG4: small-x and diffraction / **23**

Measurement of exclusive pi+pi- and rho0 meson photoproduction at HERA

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Exclusive photoproduction of $\rho^0(770)$ mesons is studied using the H1 detector at the ep collider HERA. A sample of about 900000 events is used to measure single- and double-differential cross sections for the reaction $\gamma p \to \pi^+\pi^- Y$. Reactions where the proton stays intact ($m_Y = m_p$) are statistically separated from those where the proton dissociates to a low-mass hadronic system ($m_p < m_Y < 10$ GeV). The double-differential cross sections are measured as a function of the invariant mass $m_{\pi\pi}$ of the decay pions and the squared 4-momentum transfer t at the proton vertex. The measurements are presented in various bins of the photon-proton collision energy $W_{\gamma p}$. The phase space restrictions are $0.5 < m_{\pi\pi} < 2.2$ GeV, $|t| < 1.5$ GeV^2, and $20 < W_{\gamma p} < 80$ GeV. Cross section measurements are presented for both elastic and proton-dissociative scattering. The observed cross section dependencies are described by analytic functions. Parametrising the $m_{\pi\pi}$ dependence with resonant and non-resonant contributions added at the amplitude level leads to a measurement of the $\rho^0(770)$ meson mass and width at $m_\rho = 770.8^{+2.6}_{-2.7}$ (tot.) MeV and $\Gamma_\rho = 151.3^{+2.7}_{-3.6}$ (tot.) MeV, respectively. The model is used to extract the $\rho^0(770)$ contribution to the $\pi^+\pi^-$ cross sections and measure it as a function of t and $W_{\gamma p}$. In a Regge asymptotic limit in which one Regge trajectory $\alpha(t)$ dominates, the intercept $\alpha(t=0) = 1.0654^{+0.0098}_{-0.0067}$ (tot.) and the slope $\alpha\,(t=0) = 0.233^{+0.067}_{-0.074}$ (tot.) GeV^{-2} of the t dependence are extracted for the case $m_Y = m_p$.

Eur.Phys.J.C80 (2020), 1189 [arxiv:2005.14471]

WG5: Heavy ions / **26**

Recent results on soft and hard probes at RHIC

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In this talk, recent results from selected topics on soft and hard probes by experiments STAR and PHENIX at RHIC will be presented. Besides heavy-ion collisions at $\sqrt{s_{\rm NN}} = 200$ GeV, RHIC has delivered collisions at lower energies in recent years, driven by the STAR BES-II program, ranging from $\sqrt{s_{\rm NN}} = 27$ GeV to $\sqrt{s_{\rm NN}} = 3$ GeV.

At top RHIC energies, heavy flavor hadrons are a valuable probe to study properties of the quark gluon plasma created in large systems, while their measurements in smaller systems can help us

study cold nuclear matter effects. At lower energies, measurements of strange and light flavor hadrons can help systematically investigate the properties of QCD matter at finite baryon densities. Finally, at the lowest energy achieved from the STAR fixed target setup, $\sqrt{s_{\rm NN}} = 3$ GeV, measurements on the collective flow of light and strange hadrons, particle yield ratios, hypernuclei lifetime and binding energy will be presented, and implications on the produced QCD medium properties will be discussed.

WG3 / **29**

ALICE results on long- and short-range correlations in high multiplicity pp collisions (15+3)

Author: Jasper Parkkila[1]

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In this talk, we present the latest results on two-particle correlations in high-multiplicity pp events from the ALICE Collaboration. In addition to the traditional long-range ridge studies, we present a new differential study in high-multiplicity pp collisions which contain a high-momentum charged particle or reconstructed jet, in order to determine whether long-range correlations are correlated with hard processes [1]. Furthermore, we perform a flow-extraction method using a low-multiplicity template, and present the non-flow free flow harmonics. The results are compared to the Pythia and EPOS Monte Carlo models which employ different mechanisms to generate ridge-like features, and to the results obtained in other LHC experiments.

[1] JHEP 05 (2021) 290, arXiv:2101.03110

WG2: Double Parton Scattering / **30**

Double parton distributions in colour space: perturbative splitting and positivity bounds

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Co-authors: Jonathan Gaunt [2]; Markus Diehl [1]

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Double parton scattering (DPS) and double parton distributions (DPDs) are sensitive to non-trivial colour correlations between partons inside a hadron. At small inter-parton distances the leading contribution to DPDs is due to a perturbative splitting mechanism, which makes it possible to calculate DPDs in perturbation theory in this regime. We compute this contribution at next-to-leading (NLO) order for all possible colour correlations.

With these NLO DPDs we can show that positivity bounds for colour space DPDs can be violated at NLO. We furthermore find that even at LO positivity can be violated by evolution from lower to higher scales, in contrast to the situation for ordinary PDFs and for colour singlet DPDs.

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Combining single and double parton scatterings in a parton shower

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I describe the Monte Carlo code for simulating double parton scattering, dShower, and explain how this can be consistently combined with a single parton shower to simulate the combination of single and double parton shower without double counting. Based on JHEP10(2020)012.

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Overview of DPS in perturbative QCD

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In nucleon-nucleon scattering processes, double parton scattering (DPS) happens when two partons from each nucleon undergo two separate hard interactions. The cross section relative to this phenomenon is power-suppressed with respect to the traditional single parton scattering (SPS), but under some conditions it becomes comparable to the SPS.
In this talk we give an overview of the theoretical description and formalism of DPS in perturbative QCD, which involves a non-trivial extension of the classical SPS theory to processes with two partonic currents. We focus on the DPS cross section formula and its factorization, and on the double parton distributions (DPDs), which are the DPS analog of PDFs.

WG1: MB and UE / 33

A PYTHIA 8 Underlying Event Tune For RHIC Energies

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In this talk we will report a new underlying event tune for the PYTHIA 8 Monte Carlo event generator that is applicable for hadron collisions primarily at $\sqrt{s}$ ranges available at the Relativistic Heavy-Ion Collider (RHIC). This study is the first tuning exercise of the multi-parton interactions/underlying event parameters in PYTHIA 8 utilizing RHIC data at $\sqrt{s}$ = 200 GeV. We compare our new PYTHIA 8 tuned predictions to mid-rapidity inclusive $\pi^{\pm}$ spectra, jet sub-structure, Drell-Yan production, and underlying event observables from RHIC and the Tevatron, as well as underlying event data from the Large Hadron Collider. With respect to the default PYTHIA 8 Monash Tune, the new tune shows significant improvements in the description of the experimental data across all center-of-mass energies used in the tuning. Additionally, we explore the validity of PYTHIA 8 predictions for forward rapidity $\pi^{\pm}$ in $\sqrt{s}$ = 200 GeV collisions.

WG3 / 36

ALICE strange particles and fragmentation measurements (15+3)

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The results from the ALICE pp and p-Pb program show intriguing trends resembling those of nucleus-nucleus collisions usually attributed to quark-gluon plasma formation. One of these measured effects is enhanced production of (multi-)strange particles with respect to pions (a.k.a. the strangeness enhancement) gradually rising from low-multiplicity to high-multiplicity pp or p-Pb collisions where production rates of (multi-)strange particles similar to peripheral Pb-Pb collisions are reached.
In pp or p-Pb collisions, the strange quarks can be created either in hard processes (jets) or soft processes (underlying events). Two experimental approaches can address the strange quark production in the jet fragmentation: direct one using strange hadron tagged jet reconstruction or via two-particle correlations with strange particles. Both the approaches benefit from excellent identification of strange hadrons up to high transverse momentum in the ALICE detector. In the presentation, we report on strange mesons and baryons production in the jet and out-of-the jet and the role of particles produced from jet fragmentation in the strangeness production in high-multiplicity pp or p-Pb collisions.

WG2: Double Parton Scattering / 37

DPS in pA collisions at LHC revisited

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Abstract
We present results on two dijets, Wjj, and Zjj production via double parton scattering in pA collisions at the LHC. We perform the analysis at leading and for the case of Zjj next-leading order accuracy with different sets of cuts on jet transverse momenta and accounting for the single parton scattering background. By exploiting the experimental capability to measure the centrality dependence of the cross section, we discuss the feasibility of DPS observation in already collected data at the LHC and in future runs.
The talk is based on our recent papers:
1. B. Blok, F.A. Ceccopieri
Published in: Eur.Phys.J.C 80 (2020) 8, 762
2. B. Blok, F.A. Ceccopieri
Published in: Phys.Rev.D 101 (2020) 9, 094029
3. . B. Blok, F.A. Ceccopieri
Published in: : Eur.Phys.J.C 80 (2020) 3, 278

WG3 / 38

The three point asymmetric cumulants in high multiplicity pp collisions (15+3)

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We study the inuence of quantum interference and colour flow on three point correlations described by asymmetric cumulants in high multiplicity events in pp collisions. We use the model previously developed for the study of the collectivity in symmetric cumulants. We show that the resulting three point asymmetric cumulant is in qualitative agreement with the experimental data for the same parameters of the model as it was with the symmetric cumulants. Our results show that the initial state correlations must play a major role and may be even dominant in the explanation of the correlations in high multiplicity pp events.

WG4: small-x and diffraction / 39

Double parton scattering via photon-proton interactions and the transverse proton structure

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In this contribution, we present possible appealing advantages offered by double parton scattering (DPS) processes via photon-proton interactions. In fact, as discussed in the proton-proton collisions framework, the DPS cross section depends on the double parton distribution functions (dPDFs) of the protons. These new quantities encode new information on the 3D partonic structure of the proton, complementary to TMDs and GPDs. In fact, dPDFs are sensitive to unknown double parton correlations in hadrons which cannot be accessed through, e.g., GPDs. However, dPDFs are almost unknown and, in particular, their dependence on the transverse distance of partons. In our analyses [1, 2, 3, 4] we investigated the relevance of both perturbative and non perturbative double parton correlations in dPDFs. Moreover, our collaboration studied the impact of these effects on the experimental observable called effective cross section, σ_{eff} [5, 6]. However, as proved in Refs. [7, 8] in proton-proton collisions, only limited information on the partonic proton structure can be extracted from data due to the lack of information on dPDFs and their relative first moment called effective form factor (eff), the latter entering the definition of σ_{eff}. Therefore, in Ref. [12], we studied the possibilities offered by DPS initiated by quasireal photons. In fact, in this case, the offshellness of the photons is controlled by measuring leptons, proton or ions from the impinging beam scattered at low angle. At such low virtualities, the photon will fuctuate hadronically and/or electromagnetically in a $q-\bar{q}$ pair which then initiates the double parton scattering with the proton. In this scenario, the photon transverse size could be almost controlled by measuring the virtuality and, in turn, the interaction rate in the DPS mechanism. Such a condition leads to the extraction of information on the transverse proton structure. In Ref. [12] we prove that the dependence of $\sigma^{\gamma p}_{eff}(Q^2)$ on the photon virtuality Q^2 could be related to the mean transverse distance between two partons in the proton active in the DPS process. In addition, different models of the photon and proton effs have been used to calculate, for the first time, $\sigma^{\gamma p}_{eff}(Q^2)$. These results have been then used to estimate the DPS cross section for the four jets production via DPS for the HERA kinematics. In fact, the ZEUS collaboration reported significant MPI effects in this channel for the four jets cross sections, and exposed in their analyses possible contamination of the DPS processes. By estimating the expected number of events at given integrated luminosity, we conclude that DPS process in photoproduction gives a significant fraction of the four jet production cross section if cuts on transverse momenta of the jets are low enough.

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WG5: Heavy ions / **42**

Double and triple parton scatterings in heavy-ion collisions

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This is a 10' presentation requested for the WG5 discussion session on Friday Oct. 15th.

WG3+WG5 common session / **43**

Opportunities of OO and pO collisions at the LHC (20+5)

Authors: Jasmine Brewer[1]; Aleksas Mazeliauskas[1]; Alexander Huss[1]; Wilke van der Schee[1]

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I will discuss the opportunities of the upcoming oxygen-oxygen (OO) and proton-oxygen (pO) run at the LHC. I will briefly present results and projections from the recent dedicated workshop and highlight the unique physics accessible in this run. Measuring partonic energy loss (through suppression of hadron or jet spectra) in OO would be ground-breaking but poses challenges since there is likely not time in the short run for a pp reference measurement at the same energy. I will discuss the precision and accuracy of constructing a pp baseline for the oxygen run, either from perturbative QCD or from interpolation of spectra measurements at nearby energies. I will finally highlight a new proposal to bypass the need for constructing a pp reference by measuring the ratio of OO or pO spectra to pp spectra at a different center-of-mass energy.

WG5: Heavy ions / **44**

Accessing the initial conditions of ultrarelativistic heavy-ion collisions

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The primary goal of the ultrarelativistic heavy-ion collision program at the LHC is to study the quark-gluon plasma (QGP) properties, a state of strongly interacting matter that exists at high temperatures and energy densities. However, the lack of knowledge on the initial conditions of heavy-ion collision results in a significant uncertainty of the extraction of the transport properties of QGP.

In this talk, I will present the latest developments of multi-particle correlations. I will show that the newly proposed mixed harmonic correlation of various moments of anisotropic flow coefficients can provide strong constraints on the correlations between various moments of eccentricity coefficients in the initial conditions. Both hydrodynamic model predictions and ALICE measurements will be discussed. In addition, I will discuss the newly proposed correlation between mean transverse momentum and anisotropic flow coefficients, which could reflect the size and shape of the initial state and give direct access to the initial conditions. I will present the newest experimental measurements from both RHIC and the LHC experiments, as well as several recent theoretical model predictions. I will further show that the current state-of-the-art understanding of the initial conditions and the QGP properties relies on the Bayesian analyses, which are all based on the TRENTo initial state model and fail completely in describing the experimental data. The potential solutions will be discussed in the end.

WG5: Heavy ions / **45**

Neutron production in ZDC as a probe of the dynamics of hard gamma A and pA interactions

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Neutron production in ZDC as a probe of the dynamics of hard gamma A and pA interactions.

WG3 / **46**

Jet quenching in small systems (20+5)

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We discuss recent results on possible jet quenching in collisions of small
systems: in pp, pA and oxygen-oxygen collisions. Calculations of the radiative and collisional parton energy loss are performed for the temperature dependent running QCD coupling. We use parametrization of $\alpha_s(Q,T)$ which has a plateau around $Q \sim \kappa T$ (it is motivated by the lattice calculation of the effective QCD coupling in the QGP). The parameter κ has been fitted to the LHC data on the nuclear modification factor R_{AA} in heavy ion collisions. Using the optimal κ we perform calculations of R_{pp}, R_{pPb}, and R_{AA} and v_2 for O+O collisions. We find that predictions for R_{OO} may differ substantially for scenarios with and without mini-QGP formation in pp collisions.
We show that the available data on R_{pPb} may be consistent with the QGP formation in pp and pPb collisions. However, a scenario with the QGP formation only in pPb collisions is excluded.

WG3+WG5 common session / **50**

QCD and Relativistic Hydrodynamics from pp to AA (20+5)

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One of the biggest open questions in the study of nuclear collisions is the proper understanding of collective behavior and, in particular, whether a unified framework can be found which simultaneously describes the relevant features of this behavior in all collision systems. To date, a number of such frameworks have been proposed, including that of relativistic hydrodynamics. This approach models a collision's evolution using the equations of relativistic fluid dynamics, thereby attributing the observed collective behavior to the fluid-like evolution of the quark-gluon plasma (QGP).

In this talk I will review some recent challenges to the applicability of the hydrodynamic framework in nuclear collisions. These challenges, which become particularly acute in small systems, arise from the large gradients and non-equilibrium corrections present in nuclear collisions and the fact that, as recently demonstrated, these lead readily to violations of the hyperbolic character of the hydrodynamic equations of motion and/or of relativistic causality itself. Moreover, these challenges turn out to be present even in models which have been explicitly tuned to match the experimental data. I will suggest some broad implications of these results for the ongoing debate about the nature and origins of collectivity in nuclear collisions.

WG5: Heavy ions / **52**

Overview on quarkonia and heavy-flavor physics at the LHC

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The production of quarkonia and open heavy-flavor hadrons in relativistic heavy-ion collisions has been widely explored by all LHC experiments and represents a valuable tool for probing the properties of the quark-gluon plasma (QGP). In fact, since heavy quarks, charm and beauty, are produced during the hard parton-parton scattering, they experience the entire evolution of the fireball. On one side, the suppression of quarkonium bound states by the QGP, as well as the charmonium regeneration by (re)combination of charm quarks in a strongly interacting medium, are sensitive to the medium properties. On the other, the measurement of open heavy-flavor hadron production can provide us important information on the heavy quarks' energy loss and hadronization mechanism. Moreover, the measurement of the azimuthal anisotropy coefficients (v_2, v_3) for different hadron species allows to assess the collective behavior of heavy quarks in an expanding medium.\\

In this contribution, recent quarkonium and heavy flavor measurements in nucleus-nucleus collisions obtained at the LHC. In particular, the nuclear modification factor for various hadrons and particle species ratios will be shown as a function of transverse momentum, centrality and multiplicity. The latest measurements of flow coefficients for quarkonia and heavy-flavor hadrons will be also presented.

WG3 / **53**

Collectivity in small systems at RHIC (20+5)

Author: Julia Velkovska[1]

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The quark-gluon plasma (QGP) produced in ultra-relativistic collisions between large nuclei, such as gold or lead has vanishingly small specific viscosity making it one of the most "perfect"liquids known. Experimentally, the near-perfect liquid manifests itself in a collective flow of the produced particles, and measurements of the collective flow patterns have been a key to extracting the QGP properties. However, collective effects are also observed in small collision systems, such as proton-nucleus or even proton-proton collisions, which were originally not expected to produce QGP. In the quest for understanding how the perfect liquid behavior emerges, the PHENIX and STAR collaborations at RHIC performed a series of measurements in several small systems. Gold nuclei were collided with protons, deuterons, and 3He nuclei at a nucleon-nucleon center-of-mass energy of 200 GeV, and a beam energy scan was performed with deuteron-gold collisions. This talk will review the RHIC results from the small-system geometry and beam-energy scans and discuss our current understanding of the various effects that contribute to the observed collectivity in small collision systems at RHIC.

WG2: Double Parton Scattering / **55**

ATLAS measurements of Double Parton Scattering

Author: Kostas Kordas[None]

The ATLAS collaboration has studied signatures of double-parton scattering in inclusive production of four isolated leptons at proton-proton collision energy of 8 TeV and in inclusive production of four jets at 7 TeV. The fraction of events originating from double-parton scattering has been extracted using dedicated techniques and used to measure the effective cross section in both analyses. Distributions sensitive to the presence of double parton scattering in the four-jet event sample were unfolded to the particle level and compared to various tunes of a selected Monte Carlo simulation.

WG2: Double Parton Scattering / **56**

Double-parton effects in production of fully heavy tetraquarks in proton-proton collisions

Authors: Antoni Szczurek[None]; Rafal Maciula[None]; Wolfgang Schafer[None]

We discuss the production mechanism of a new state,
a fully charm tetraquark, discovered recently by the LHCb at
M = 6.9 GeV in the $J/\psi J/\psi$ channel.
Both single parton scattering (SPS) and double parton scattering (DPS)
mechanisms are considered. We calculate the distribution in the invariant
mass of the four-quark system M_{4c} for SPS and DPS production of
$cc\bar{c}\bar{c}$ in the k_t-factorization approach with modern
unintegrated gluon distribution functions (UGDFs).
The so-calculated contribution of DPS is almost two orders of
magnitude larger than the SPS one, but the tetraquark formation
mechanism is unknown at present.
We construct a simple coalescence model of the tetraquark out of
$c\bar{c}\bar{c}$ continuum.
Imposing a mass window around the resonance position we calculate the
corresponding distribution in $p_{t,4c}$ – the potential tetraquark
transverse momentum. The cross section for the $J/\psi J/\psi$ continuum
is calculated in addition, again including SPS (box diagrams) and
DPS contributions which are of similar size.

The formation probability is estimated trying to reproduce the LHCb signal-to-background ratio. The calculation of the SPS $gg \to T_{4c}(6900)$ fusion mechanism is performed in the k_T-factorization approach assuming different spin scenarios (0^+, 0^- and 2^+). The 2^+ and 0^+ assignment is preferred over the 0^- one by a comparison of the transverse momentum distribution of signal and background with the LHCb preliminary data assuming the SPS mechanism dominance.
There is no microscopic approach for the DPS formation mechanism of tetraquarks at present as this is a complicated multi-body problem.

We do similar analysis for FCC energy $\sqrt{s}$ = 100 TeV.
We predict the production cross section order of magnitude larger than its counterpart for the LHC.
We discuss also a possibility to observe the T_{4c} state in the $\gamma\gamma$ channel. The signal-to-background ratio is estimated.

We discuss also production of $c\bar{c}b\bar{b}$ tetraquarks and discuss how the results depend on the mass of such an object.

WG2: Double Parton Scattering / 57

Double parton scattering studies using gauge bosons and jets at CMS (15+3)

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WG2: Double Parton Scattering / 58

ATLAS measurements of Double Parton Scattering (15+3)

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WG2: Double Parton Scattering / 59

Importance of jet fragmentation properties to study DPS (15+3)

WG2: Double Parton Scattering / 60

Review of DPS in perturbative QCD (20+5)

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WG2: Double Parton Scattering / 61

Double parton distributions in colour space: perturbative splitting and positivity bounds (20+5)

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WG2: Double Parton Scattering / 62

First observation of triple-J/psi production in pp collisions, and constraints on double and triple parton scatterings (15+3)

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WG2: Double Parton Scattering / 63

LHCb measurement of double parton scattering in pPb collisions (15+3)

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WG2: Double Parton Scattering / 64

Double-parton effects in production of fully heavy tetraquarks in proton-proton collisions (15+3)

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WG2: Double Parton Scattering / 65

Study of parton correlations via DPSs in associated quarkonium production in high energy accelerator experiments (20+5)

WG2: Double Parton Scattering / 66

Sum rules for triple parton distribution function (20+5)

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WG2: Double Parton Scattering / 67

Combining single and double parton scatterings in a parton shower (cancelled)

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WG2: Double Parton Scattering / **68**

DPS in pA collisions at LHC revisited (20+5)

WG3 / **69**

Leptons from HF decays : measurements and inferences towards small systems

WG5: Heavy ions / **70**

Heavy-Ion Physics at the LHCb

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WG5: Heavy ions / **71**

Overview talk on recent soft probes in heavy-ion physics at the LHC

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WG5: Heavy ions / **72**

MPI & Jet Physics in Heavy-Ion Collisions

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WG5: Heavy ions / **73**

Overview talk on quarkonia and heavy-flavor physics at the LHC

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WG5: Heavy ions / **74**

Jets and UPC physics in heavy-ion collisions at the LHC

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WG5: Heavy ions / **75**

Role of MPI to HI

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10 min talk as input for round-table discussion.

WG5: Heavy ions / **76**

Role of MPI to HI

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10 min talk as input for round-table discussion.

WG5: Heavy ions / **77**

Role of MPI to HI

10 min talk as input for round-table discussion.

WG5: Heavy ions / **78**

Round-table discussion

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WG3 / **79**

ATLAS and CMS results on collectivity in small-systems (20+5)

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This talk presents an overview of recent measurements from the ATLAS and CMS collaborations that study collective behavior in p+Pb and pp collisions.For p+Pb collisions, measurements of collec-

tive behavior involving strange, charm and bottom hadrons are presented. Measurements of elliptic anisotropy in Ultra-peripheral p+Pb collisions, which are
in fact p+γ collisions, are presented and compared to corresponding measurements in hadronic p+Pb collisions. Several measurements that investigate the long-range correlations observed in pp collisions, commonly called the "ridge", are presented. A study of the dependence of the ridge on the presence of a hard process in the event, namely a Z-boson, is presented, and its implications are discussed. Studies of the long-range correlations in pp collisions involving heavy-flavor hadrons are presented. Finally, correlation measurements with an active rejection of particles associated with semi-hard processes, such as low-pT jets, are also discussed. These measurements can give further insight into the origin of the pp ridge.

WG3 / **80**

Collectivity in small systems: the initial state perspective (20+5)

I discuss the physical origin of collective like signals in collisions of small systems from the perspective of initial state structure. Recent theoretical developments and directions of CGC inspired research are described.

WG3 / **81**

Search for collective behaviour and multiparton interactions in ep scattering at HERA (20+5)

Collective behaviour of final-state hadrons is studied in ep scattering using the H1 and ZEUS detectors at HERA. Measurements of two- and four-particle azimuthal correlations in both DIS and photoproduction are presented. Ridge yields are extracted from fits to two-particle correlations with H1 data. Comparisons of the magnitudes and signs of the first- and second-harmonic of two-particle correlations are made with ZEUS data. Four-particle cumulant correlations are observed to be positive. The results do not indicate the kind of collective behaviour observed at RHIC and the LHC in high-multiplicity hadronic collisions. The possibility of multiparton interactions are studied in photoproduction with ZEUS. Comparisons of PYTHIA predictions with the measurements strongly indicate the presence of multiparton interactions from hadronic fluctuations of the exchanged photon.

WG1 / **82**

Soft QCD and Phenomenology with Herwig 7

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WG1 / **83**

Predicting strangeness yields in small and large systems with PYTHIA/Angar

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WG1: MB and UE / 84

PYTHIA8: soft QCD model, news and updates

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WG1: MB and UE / 85

MB & UE: review of measurements and MC tuning at CMS

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WG1: MB and UE / 86

MB & UE: review of measurements and MC tuning at ATLAS

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WG1: MB and UE / 87

Minimum Bias and Underlying Event studies in pp collisions at ALICE

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WG1: MB and UE / 88

MB & UE: review of measurements at LHCb

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WG1: MB and UE / 89

H1: lepton-jet correlation in deep-inelastic scattering

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WG1: MB and UE / 90

Status of the GENEVA Monte Carlo event generator

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WG1: MB and UE / 91

The intrinsic kT in LO and NLO parton showers

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WG1 / 92

A PYTHIA 8 Underlying Event Tune For RHIC Energies

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WG4: small-x and diffraction / 93

Very forward particle production and searches (FASER, etc)

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WG4: small-x and diffraction / 94

Parton distribution functions: measurements and interpretations

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WG4: small-x and diffraction / 95

Results on diffraction and exclusive production

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WG4: small-x and diffraction / 96

Results from peripheral and ultra-peripheral collisions at the LHC

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Welcome and Introduction

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WG1: MB and UE / 98

WG1: summary and discussion (20´+15´)

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WG2: Double Parton Scattering / 99

WG2: summary and discussion (20´+15´)

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WG3 / 100

WG3: summary and discussion (20´+15´)

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WG4: small-x and diffraction / 101

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WG5: Heavy ions / 102

WG5: summary and discussion (20´+15´)

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directions to excursion and dinner

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