Diffraction and Low-x 2024

Sunday 8 September 2024 - Saturday 14 September 2024

Hotel Tonnara Trabia, Palermo, Sicily

Book of Abstracts

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The LHCspin project

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The goal of LHCspin is to develop, in the next few years, innovative solutions and cutting-edge technologies to access spin physics in high-energy and high-intensity collisions of the LHC beam against a polarized fixed target.
This ambitious task poses its basis on the recent success of SMOG2, the unpolarized gas target installed in front of the LHCb spectrometer. SMOG2, already itself a unique project, will allow to carefully study the dynamics of the beam-target system, and clarify the potentiality for an innovative physics program at the LHC.
The forward geometry of the LHCb spectrometer (2<⊠<5) is perfectly suited for the reconstruction of particles produced in fixed-target collisions. This configuration, with center-of-mass energies ranging from 115 GeV in pp interactions to 72 GeV in collisions with nuclear beams, allows to cover a wide backward rapidity region, including the poorly explored high-x regime, with unique probes.
With LHCspin, LHCb will become the first experiment delivering simultaneously unpolarized beam-beam collisions at √s=14 TeV and both polarized and unpolarized beam-target collisions.
The status of the project is presented along with a selection of physics opportunities.

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Saturation within the reach of the LHC: Incoherent J/ψ production at large |t|

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We identify a new way of pinpointing the presence of saturation effects in the LHC data by looking at incoherent J/ψ production at large |t|. We use an energy-dependent hotspot model to show that saturation effects are manifested through a fall-off of the incoherent vector meson production cross section. This fall-off comes from the reduced variance of possible target configurations due to parton overlap at Mandelstam-t scales, where individual hotspots become important.

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Next-to-leading order photon+jet production

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Using the CGC effective theory together with the hybrid factorisation, we study forward photon+jet production in proton-nucleus collisions beyond leading order. We first compute the "real" next-to-leading order (NLO) corrections, i.e. the radiative corrections associated with a three-parton final state, out of which only two are being measured. Then we move to the "virtual" NLO corrections to di-jet production, in which a gluon loop is included as a part of the amplitude, before or after the measurement. Each of these loop diagrams diverges, and we explain our treatment in order to obtain finite expression for the cross section. We explicitly work out the interesting limits where

the unmeasured gluon is either a soft, or the product of a collinear splitting. We find the expected results in both limits: the B-JIMWLK evolution of the leading-order dijet cross-section in the first case (soft gluon) and, respectively, the DGLAP evolution of the initial and final states in the second case (collinear splitting).

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How does Λ hyperon obtain polarization?

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In the 1970s, the unexpected discovery of transverse Λ polarization in unpolarized proton-Beryllium collisions marked the beginning of investigating spin phenomena in high-energy physics. Over the past 50 years, similar transverse Λ polarization has been observed in various collision systems, including hadron-hadron collisions, lepton-hadron deep inelastic scattering, and electron-positron annihilation. Despite numerous promising models and theoretical frameworks, the underlying mechanism behind this polarization phenomenon remains inconclusive to this day. However, in both longitudinally and transversely polarized lepton-hadron and hadron-hadron collisions, it has been found that the Λ hyperon does not acquire polarization relative to the initial parton spin polarization direction. Understanding how the Λ hyperon does or does not obtain its spin has become one of the most crucial questions in understanding hadron spin structures and the nonperturbative hadronization process.

In this talk, I will introduce two new ideas to tackle this question: 1) measurement of spin-spin correlation to understand the impact from initial-state spin entanglement as well as final-state hadronization effect; 2) deep exclusive meson production to reveal the direction of Lambda hyperon polarization in the simplest configuration. Experimental data and future opportunities will be discussed.

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On the Quarkonium Collinear Fragmentation in a VFNS

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We report progress on the Heavy-Flavor Non-Relativistic Evolution (HF-NRevo) setup, a novel methodology to address the quarkonium formation within the fragmentation approximation. Our analysis addresses the moderate to large transverse-momentum regime, where the production mechanism based on the leading-twist collinear fragmentation from a single parton is expected to prevail over the higher-twist emission, directly from the hard-scattering subprocess, of the constituent heavy-quark pair. We rely upon Non-Relativistic-QCD (NRQCD) next-to-leading calculations for all the parton fragmentation channels to vector (J/ψ and Υ) and pseudoscalar (η_c and η_b) quarkonia, which we take as proxies for initial-scale inputs. Thus, a complete set of variable-flavor number-scheme fragmentation functions, named NRFF1.0, are built through standard DGLAP evolution. Statistical errors are assessed via a Monte Carlo, replica-like approach that also accounts for Missing Higher-Order Uncertainties (MHOUs). The link between the NRFF1.0 approach and the MCscales one will be discussed. As a prospect, the use of HF-NRevo to address the quarkonium-in-jet fragmentation will be highlighted.

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Fragmentation of heavy quarks

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Heavy flavored mesons produced with high p_T demonstrate specific features of the production mechanism, such as: (i) short time of gluon radiation by a highly virtual heavy quark; (ii) short formation time of the heavy flavored meson wave function; (iii) enhancement of the fragmentation function $D_{b/B}(z)$ at large fractional momenta $z \to 1$; (iv) short mean free path in the medium (no color transparency). In particular these features explain the observed very different p_T dependences of the nuclear ratio R_{AA} for J/ψ produced directly and indirectly (from B-decays). Data for D-meson production are explained as well.

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Transverse Single Spin Asymmetry of Electromagnetic Jets for Inclusive and Diffractive Processes at Forward Rapidity in p^{\uparrow}+p Collisions at STAR

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In recent decades, the unexpectedly large transverse single spin asymmetry (A_N) has been observed in inclusive hadron productions at forward rapidities in $p^{\uparrow}$+p collisions at various center-of-mass energies ($\sqrt{s}$). Several theories have been proposed to explain this phenomenon, including the twist-3 contributions within the collinear factorization framework, the transverse-momentum-dependent contributions from the initial-state quark and gluon (Sivers functions), and/or final-state Collins fragmentation functions. However, there are indications from experiments that diffractive processes might also play a role in the observed A_N [1].

The STAR experiment provides an ideal opportunity to investigate the A_N in the diffractive processes using the Forward Meson Spectrometer and Roman Pot detectors.
This talk will present the preliminary results on A_N for inclusive and diffractive EM-jets at forward rapidity ($2.6 < \eta < 4.2$) in $p^{\uparrow}$+p collisions at $\sqrt{s} = 200$ GeV at STAR. The discussion will include a multi-dimensional study of A_N for EM-jets in inclusive processes, along with the preliminary results for A_N in the diffractive processes. Additionally, there will be a discussion on the contribution of A_N from diffractive processes to the overall inclusive processes. Finally, the analysis status of the inclusive and diffractive processes at $\sqrt{s} = 510$ GeV at STAR will be mentioned.

1 J. Adam et al., Phys. Rev. D 103, 092009 (2021)

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Future LHC Measurements for Cosmic Ray Induced Air Shower Modelling

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Event generators simulating soft hadronic interactions have so far been tuned with measurements of experiments at particle accelerators in the central collision region, most prominently with charged particle spectra. However, if one particle created in a hadronic interaction with low momentum transfer carries a large fraction of the beam energy, it will be emitted at very high rapidities, i.e. in the ultra-forward region. For extensive air showers (EAS) induced by cosmic rays (CR), these highly energetic secondary particles have a large impact on the further development of the shower. For analyses of gamma ray induced air showers at imaging atmospheric Cherenkov telescopes (IACTs), CR induced air showers with one highly energetic neutral pion pose the most important background process. Currently, large differences in the event generators' predictions are observed, leading to large systematic uncertainties. Therefore measurements of neutral pion spectra in the ultra-forward region in hadron-hadron collisions at particle accelerators are of very high relevance for the background modelling and systematic uncertainty reduction of cosmic gamma ray analyses with IACTs. In this talk, the optimal energy and rapidity region for this kind of measurement will be discussed as well as regions already covered by LHC experiments and potential future measurements.

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Measurements of the Z^0 cross section and transverse single spin asymmetry in 510 GeV p+p collisions

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In this talk, we will present the recent results on cross section and transverse single spin asymmetry (TSSA) of Z^0 measured by the STAR experiment. The cross section results combine 500/510 GeV p+p data from 2011, 2012, 2013 and 2017, corresponding to a total luminosity of 680 pb^{-1}. The differential Z^0 cross section, measured as a function of the boson's transverse momentum, provides important constraints on the energy dependence of the transverse momentum dependent parton distribution functions (TMDs). The TSSA of Z^0 is measured using 510 GeV p$^{\uparrow}$+p data from 2017 with the integrated luminosity of 340 pb^{-1}. This observable is sensitive to one of the TMDs, the Sivers function, which is predicted to have the opposite sign in p+p$\rightarrow$ W/Z+X from that observed in semi-inclusive deep inelastic scatterings. Our data aim to investigate the non-universality of the Sivers function.

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Odderon contribution in light of the LHC low-t data

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We show an analysis of elastic scattering pp and $\bar{p}p$ data at low momentum transfer $|t| < 0.1$ GeV^2 within large collider energy interval $\sqrt{s} = 50$ GeV - 13 TeV in order to evaluate quantitatively the

possible Odderon contribution. We use a two-channel eikonal model, which naturally accounts for the screening of the Odderon amplitude by C-even (Pomeron) exchanges.

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Bose-Einstein correlations in small collision systems at LHCb

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Due to its unique pseudorapidity coverage (2 < eta < 5) and excellent performance, the LHCb detector allows the study of various aspects of particle correlations at large rapidities and low transverse momenta. The Bose-Einstein correlations of same-sign charged pions are measured in proton-proton collisions at √s = 7 TeV centre-of-mass energy and proton-lead collisions at a nucleon-nucleon centre-of-mass energy of
√sNN = 5.02 TeV. Both measurements are the first of this type performed in the forward region at LHC energies. Correlation parameters are determined for different regions of charged-particle multiplicity, which behaviour is consistent with observations from other experiments at the LHC in the central rapidity region. The measured correlation radii scale linearly with the cube root of the charged-particle multiplicity, being compatible with predictions based on the hydrodynamic models. The hints for a dependence of the correlation radius on pseudorapidity may also be observed. The so-called small systems, e.g. proton-proton and proton-lead collisions,characterized by significantly shorter lifetimes than the heavy-ion systems, may provide a better experimental insight into the early system dynamics and initial geometry. Thus, the present results make an important contribution to the understanding of the particle production process in the forward direction at LHC energies.

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Looking for BFKL resummation and saturation at the LHC

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We first present the results of the NLL BFKL jet gap jet cross section calculations including the NLO impact factors. We then describe the forward dijet production at the LHC within an impact parameter dependent TMD approach. We finish the talk by comparing the vector meson cross section measurement in p Pb and Pb Pb using the BFKL and the BK approaches.

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Diffractive Physics Program at Electron-Ion Collider (EIC) 2nd Detector

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The Electron-Ion Collider (EIC) will be a novel experimental facility to explore the properties of gluons in nucleons and nuclei, shedding light on their structure and dynamics. The EIC community outlined the physics program of the EIC in White Paper, and the demanding detector requirements and potential technologies to deploy at an EIC detector were published in a comprehensive Yellow Report. The general-purpose detector resulting from this efforts, ePIC, is designed to perform a broad physics program. At the same time, the wider EIC community is strongly in favor of a second detector at the EIC. Having two general-purpose collider detectors to support the EIC science program, allows us to have cross-checks and control of systematic for potential scientific discoveries. The second detector should feature complementary technologies where possible. It can also focus on specific measurements that are less well addressed in ePIC. The second interaction region provides improved forward detector acceptance at low p_T and a secondary beam focus that enables to enhance the exclusive, tagging, and diffractive physics program. In this talk, I will present potential capabilities of the second detector and discuss studies related to the diffractive physics program.

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Suppression of diffraction in deep-inelastic scattering on nuclei and dynamical mechanism of leading twist nuclear shadowing

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Using the leading twist approach (LTA) to nuclear shadowing, we calculate the ratios of diffractive and usual parton distributions for a heavy nucleus (Pb) and the proton, $R_{A/p} = (f_{i/A}^{D(3)}/f_{i/A})/(f_{i/p}^{D(3)}/f_{i/p})$, for coherent and summed (coherent plus quasi-elastic) nuclear deep-inelastic scattering. We find that $R_{A/p} \approx 0.5 - 1$ for quarks as well as for the ratio of the diffractive and total cross sections $[(d\sigma_{\rm diff}/dM_X^2)/\sigma_{\rm tot}]_{eA}/[(d\sigma_{\rm diff}/dM_X^2)/\sigma_{\rm tot}]_{ep}$ and $R_{A/p} \approx 0.5 - 1.3$ for gluons in a broad range of x, including the kinematics of the Electron-Ion Collider, which reaffirms the difference from the nuclear enhancement of $R_{A/p}$ predicted in the gluon saturation framework. We demonstrate that the magnitude of $R_{A/p}$ is controlled by the cross section of the interaction of hadronic fluctuations of the virtual photon with target nucleons, which explains an enhancement of $R_{A/p}$ in the color dipole model and its suppression in LTA. We argue that the black disk limit corresponds to $R_{A/p} = 1$ and $R_{A/p}^{\rm coh} = 0.86$ for the summed and coherent scattering, respectively. Relying on an intuitive definition of the saturation scale, we show that the ratio of the saturation scales of a heavy nucleus and proton $Q_{sA}^2(b)/Q_{sp}^2(b) \approx 1$ at small impact parameters b due to the strong leading twist nuclear shadowing and diluteness of the nuclear density.

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Connections between heavy ion collisions and DIS

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We discuss recent progress in describing simultaneously various deep inelastic electron-proton/nucleus scattering (DIS) observables and flow observables in heavy ion collisions. We demonstrate how DIS

processes both probe intriguing gluon saturation phenomena, and provide important input needed to describe early stages of ultra relativistic heavy ion collisions.

In particular we discuss recent progress in describing exclusive vector meson production in ultra peripheral collisions, a process that ca be used to both probe the role of gluon saturation effects in the wave function of a heavy nucleus, and to constrain the event-by-event fluctuating nucleon and nuclear geometry [1,2]. We also highlight the possibility to probe nuclear deformations at small-x at the Electron-Ion Collider [3].

Using the Color Glass Condensate effective theory, we then describe the early stages of heavy ion collisions using the same degrees of freedom as when describing DIS observables. Coupling the early time evolution to relativistic hydrodynamics, we can consistently simulate the space-time evolution of ultra relativistic heavy ion collision where quark gluon plasma is produced. We show that when nucleon geometry is constrained by DIS data a succesfull description of flow observables in p+A collisions can be achieved. [4,5]

[1]H. Mäntysaari, F. Salazar, B. Schenke, Phys.Rev.D 109 (2024) 7, L071504 • e-Print: 2312.04194 [hep-ph]
[2] H. Mäntysaari, F. Salazar, B. Schenke, Phys.Rev.D 106 (2022) 7, 074019 • e-Print: 2207.03712 [hep-ph]
[3] H. Mäntysaari, F. Salazar, B. Schenke, C. Shen, W. Zhao, Phys.Rev.Lett. 131 (2023) 6, 062301 • e-Print: 2303.04866 [nucl-th]
[4] H. Mäntysaari, B. Schenke, C. Shen, P. Tribedy, Phys.Lett.B 772 (2017) 681-686 • e-Print: 1705.03177 [nucl-th]
[5] H. Mäntysaari, F. Salazar, B. Schenke, C. Shen, W. Zhao, in progress

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Overview of ATLAS forward proton detectors: status, performance and new physics results

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A key focus of the physics program at the LHC is the study of head-on proton-proton collisions. However, an important class of physics can be studied for cases where the protons narrowly miss one another and remain intact. In such cases, the electromagnetic fields surrounding the protons can interact producing high-energy photon-photon collisions. Alternatively, interactions mediated by the strong force can also result in intact forward scattered protons, providing probes of quantum chromodynamics (QCD). In order to aid identification and provide unique information about these rare interactions, instrumentation to detect and measure protons scattered through very small angles is installed in the beam pipe far downstream of the interaction point.
We describe the ATLAS Forward Proton 'Roman Pot' Detectors (AFP and ALFA), including their performance to date, covering Tracking and Time-of-Flight Detectors as well as the associated electronics, trigger, readout, detector control and data quality monitoring. The physics interest, beam optics and detector options for the extension of the programme into the High-Luminosity LHC (HL-LHC) era are also discussed. Finally, a glimpse on the newest results will be given.

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ATLAS ZDC for Run 3 and Run 4

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The ATLAS Zero Degree Calorimeters (ZDCs) detect neutral particles emitted at very forward rapidities in nuclear collisions at CERN's Large Hadron Collider (LHC). During Runs 1 and 2 of the ATLAS experiment, the ZDCs have been crucial for identifying spectator neutrons in lead-lead collisions and in selecting ultraperipheral collisions.
The ZDCs consist of modules of sampling hadronic calorimeters made up of alternating tungsten-fused silica rod layers that act as Cherenkov radiators. They have been upgraded for LHC Run 3 with new fused silica rods for better radiation hardness, along with low-attenuation air-core cables and new readout electronics based on the LUCROD card from ATLAS's LUCID detector. The electronic update facilitated a new all-digital triggering mechanism for improved event selections.
Also for Run 3, a new Reaction Plane Detector (RPD) was implemented. The RPD measures nuclear collision reaction planes by analyzing transverse shower profiles from spectator neutrons in the ZDC. Equipped with radiation-hard fused silica fibers of varying lengths in y direction and grouped in x direction, the 16 channels of RPD can image multi-neutron showers using a Convolutional Neural Network to optimize angular sensitivity.
The LHC absorber region will be completely rebuilt for the High Luminosity (HL) LHC, which will provide first beams in LHC Run 4. The ATLAS and CMS ZDC groups have proposed a joint project to build a next-generation HL-ZDC that will include an Electromagnetic (EM) and Hadronic section, as well as an RPD, all enclosed in a monolithic mechanical design that should simplify installation and thus reduce radiation exposure.
This talk will review the performance of the ATLAS ZDC in the first year of Run 3, and provide an outlook of the HL-ZDC detector, with particular attention to the upgraded EM section.

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Particle production in high multiplicity proton-proton collisions: a study of K^0_S, isolated photons, and D^0 mesons

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This work investigates the production of K^0_S mesons, isolated photons, and D^0 mesons in high multiplicity proton-proton (pp) collisions at fixed collision energy and forward rapidities, employing the Color Glass Condensate (CGC) framework with solutions of the running coupling Balitsky-Kovchegov (BK) equation. Results for the self-normalized yields of these final state particles are presented as a function of the multiplicity of co-produced charged hadrons, and compared with experimental data when possible. An estimate of the influence of a intrinsic charm component in the proton's wave function is also presented in the case of D^0 mesons. Our results show that a simultaneous study of isolated photon production and different hadronic final states in high multiplicity events provides an opportunity to test the description of such rare events within the CGC formalism and emphasizes the potential of future experimental investigations to disentangle initial and final state effects in high energy hadronic collisions.

Based on: Y. N. Lima, A. V. Giannini and V. P. Goncalves, Phys. Rev. C 106, no.6, 065206 (2022), Eur. Phys. J. A 60, no.3, 54 (2024), arXiv:2405.03581 (to appear in Phys. Rev. D).

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Exclusive π^0 muoproduction at COMPASS

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Hard Exclusive Meson Production is a very promising reaction to access Generalized Parton Distributions (GPDs). Measurements of the cross section for hard exclusive neutral-pion muoproduction on the proton were performed at COMPASS in 2016 and 2017 at the M2 beamline of the CERN SPS using 160\,GeV/c longitudinally polarised μ^+ and μ^- beams scattering off a 2.5 m long liquid hydrogen target. Results were obtained in a wide kinematic region with the photon virtuality Q^2 up to 8 $(\mathrm{GeV}/c)^2$ and the Bjorken variable x_B ranging from 0.016 to 0.45. We will report on the virtual-photon proton cross section averaged over the μ^+ and μ^- cross sections and on its dependence on the squared four-momentum transfer between initial and final proton in the range $0.08\,(\mathrm{GeV}/c)^2 < |t| < 0.64\,(\mathrm{GeV}/c)^2$ and on the azimuthal angle between the scattering plane and the π^0 production plane. Fitting the azimuthal dependence yields the sum of the contributions by transversely and longitudinally polarised photons as well as transverse-transverse and longitudinal-transverse interference contributions. The COMPASS results provide input to constrain GPDs, in particular chiral-odd ("transversity") GPDs.

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Study of the J/psi photoproduction with tagged forward proton in p+p collisions at STAR

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We present the first measurement of the exclusive J/ψ photoproduction in proton-proton collisions at $\sqrt{s} = 510$ GeV by the STAR experiment. Interesting physics aspect of the presented measurement is the possibility to obtain transverse momentum of exchanged photon, which is important in constraining the kinematics of the reaction. The unique Roman Pot detector system is utilized to measure forward-propagating protons from the diffractive interactions where one or both protons survive the collisions. This permits the calculation of missing transverse momentum in the collision. Conservation of momentum governing the collision dynamics allows us to equate this to the transverse momentum of the virtual photon from the interaction. The J/ψ is identified via its decay channel to electron-positron pair in the STAR central barrel detectors. We report on preliminary STAR results of J/ψ photoproduction with use of Roman Pot detectors in proton-proton collisions at $\sqrt{s} = 510$ GeV.

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Heavy flavor measurements at RHIC

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Recent open flavor and quarkonia measurements in p+p and A+A collisions from the experiments at the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory will be discussed.

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Photoproduction of Ordinary and Exotic charmonia

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The next generation of electron-hadron facilities has the potential for significantly improving our understanding of exotic hadrons. The XYZ states have not been seen in photon-induced reactions so far. Their observation in such processes would provide an independent confirmation of their existence and offer new insights into their internal structure. Furthermore, recent data on J/ψ photoproduction near threshold have shown a pattern that seems in contrast with the typical factorization hypotheses. I will discuss what are the opportunities for spectroscopy at the newly planned facilities.

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Spin physics at the EIC

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Spin physics and the 3D structure of nucleons and nuclei is a cornerstone of the science program of the Electron-Ion Collider (EIC), and the EIC offers a number of capabilities that are crucial for these measurements. It will be the world's only collider with highly polarized electron and proton beams - the latter with both longitudinal and transverse polarization. It will also be able to provide nuclear beams over a wide mass range, including polarized light ions (*e.g.*, He-3. In this talk we will look at the capabilities of the EIC, key measurements envisioned for the ePIC detector, and briefly outline additional opportunities that could be provided by a 2nd detector.

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Deep-inelastic scattering with collider neutrinos at the LHC and beyond

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Proton-proton collisions at the LHC generate a high-intensity collimated beam of forward neutrinos up to TeV energies. Recent observations of these neutrinos and the initiation of a novel neutrino physics program at the LHC motivate investigations of this previously unavailable particle beam. The kinematic region for neutrino deep-inelastic scattering (DIS) measurements at the LHC overlaps with the Electron-Ion Collider. The effect of the LHC νDIS data on proton and nuclear parton distribution functions (PDFs) is assessed by generating projections for the Run 3 LHC experiments, as well as for a selection of proposed detectors at the HL-LHC. Estimating the impact of the DIS projections in global (n)PDF analyses reveals a significant reduction of PDF uncertainties, in particular for strangeness and the valence quark PDFs. Furthermore, the effect of neutrino flux uncertainties is examined by parametrizing the correlations between a broad selection of predictions for the production of forward neutrinos in parent hadron decays. This allows determining the highest achievable precision for neutrino observations, and constraining various processes within and beyond the Standard Model. This is demonstrated by setting bounds on effective theory operators, and discussing the prospects for an experimental confirmation of the enhanced-strangeness scenario proposed to resolve the cosmic-ray muon puzzle using LHC data. Moreover, the possibility for a conclusive observation of neutrino trident scattering off a nucleus N, $\nu N \to \nu^{(\prime)}\ell^-\ell^{(\prime)+}N$, is assessed.

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Three-dimensional hadron structure from lattice QCD

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The last decade has brought a breakthrough in extracting partonic distributions from lattice QCD. The recent focus is the three-dimensional structure embodied by generalized parton distributions (GPDs) and transverse-momentum dependent PDFs (TMDs). In this talk, I will give an overview of the recent lattice efforts concerning GPDs/TMDs and discuss prospects for further work and synergy with phenomenology and experiment.

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Semihard Interactions at TeV energies

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We present the results of an analysis of the pp and $\bar{p}p$ scatterings at the LHC energies using a QCD-based model in which the energy dependence of the cross sections are driven predominantly by semihard processes of gluons in the nucleons. We show that forward quantities can be accurately described using a model where the even-under-crossing amplitude dominates at high energies.

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Inclusive J/ψ production in forward proton-proton and proton-lead collisions at high energy

Author: Patricia Gimeno Estivill[1]

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We calculate J/ψ production in forward proton-proton and proton-lead collisions applying the Color Glass Condensate+Non-Relativistic QCD formalism. Following earlier work of Kang, Ma and Venugopalan, the production of color octet heavy quarks depends on 2-point Wilson Line correlators, in contrast with the color singlet channel that depends on 2 and 4-point correlators. Unlike previous studies, we use an explicit expression for the quadrupole correlator in the large-Nc limit and also quantify the importance of finite-Nc corrections. We show predictions for the nuclear modification factor now consistently with the DIS fit and compare it to LHCb data.

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Nonperturbative Collins-Soper Kernel from Lattice QCD

Author: Swagato Mukherjee[None]

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Progresses related to lattice QCD calculations of the rapidity anomalous dimension of quark transverse-momentum-dependent distributions, i.e., the Collins-Soper (CS) kernel, will be presented. Methodological and numerical advances over the last year will be reviewed. Results from the state-of-the-art lattice QCD calculations will be presented and compared with the those from the phenomenological parametrizations of experimental data.

Flash talks / Posters / 122

TMD factorization Bridging large and small x

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QCD factorization takes on different forms in the large-x and the small-x regimes. In the large-x motivated collinear factorization, one gets the DGLAP evolution equation, whereas, in the small-x motivated rapidity factorization, the BFKL equation is the major player. To unify different regimes, a new TMD factorization based on the background field method is proposed, which not only reduces to CSS and DGLAP in the large-x limit and BFKL in the small-x limit, but also defines a general evolution away from these regimes. Such a factorization has the potential to significantly advance our comprehension of high-energy processes and the three-dimensional structure of hadrons.

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Lévy α-stable generalization of the ReBB model of elastic proton-proton and proton-antiproton scattering

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The real extended p=(q,d) Bialas-Bzdak (BB) model gives a statistically acceptable description to the proton-proton and proton-antiproton elastic scattering data (i) in the center of mass energy domain that ranges from half TeV up to 8 TeV and (ii) in a squared four-momentum transfer (t) domain that includes the diffractive interference (minimum and maximum) region but does not include the low-|t| domain, where a strong non-exponential shape characterizes the experimental data. The weak non-exponential behavior featured by the ReBB model at low -t values is not strong enough to describe the experimental observations. This can be attributed to the assumption of the p=(q,d) BB model that the quark and diquark constituents of the proton have Gaussian parton distributions, and also, the distance between these constituents has a Gaussian shape. In my talk, I present a generalized Bialas-Bzdak model, the LBB model for short, where the Gaussian distributions with $\alpha=2$ are generalized to Lévy α-stable distributions with $0<\alpha\leq 2$.

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The Axial Current and Its Divergence

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The axial current is known to exhibit the chiral anomaly, a phenomenon that has significant implications for understanding fundamental aspects of quantum field theory. While much of the research on this topic has been dormant in recent decades, recent studies have revived interest by highlighting new connections and potential applications. In this study, we present perturbative calculations that offer fresh insights into the role of the axial anomaly in helicity Parton Distribution Functions (PDFs) and Generalized Parton Distributions (GPDs). We will also discuss to what extend our perturbative results could shed new light on the internal structure of nucleons.

125

Absorptive Corrections to the Electromagnetic Form Factor in High-Energy Elastic Proton-Proton Scattering

Author: Andrei Poblaguev[1]

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Recently, it was noted that absorptive corrections to the electromagnetic form factor in high-energy proton-proton scattering are important for the theoretical interpretation of the $p^{\uparrow}p$ and $p^{\uparrow}A$ analyzing power $A_{\mathrm{N}}(t)$ measurements with the Hydrogen Jet Target polarimeter (HJET) at RHIC. Here, a concise expression for the absorptive correction was derived within the eikonal approach. The resulting analysis reveals a systematic bias, nearly independent of the beam energy, in the experimental determination of the real-to-imaginary ratio ρ when absorption effects are overlooked in the

data analysis. Quantification of this bias, as $\rho^{\text{meas}} = \rho + (0.036 \pm 0.016)_{\text{bias}}$, was achieved using a Regge fit applied to available proton-proton measurements of $\rho^{\text{meas}}(s)$ and $\sigma_{\text{tot}}^{\text{meas}}(s)$. Considering the potential impact of such an effect on the experimentally determined $A_{\text{N}}(t)$, one may enhance consistency between the HJET and STAR measurements of the hadronic spin-flip amplitude. While the sign of the bias in the value of ρ aligns with the anticipated effective increase in the proton charge radius in pp scattering due to absorption, it amplifies the observed discrepancy between $\sigma_{\text{tot}}^{\text{meas}}$ and ρ^{meas} values at $\sqrt{s} = 13\,\text{TeV}$ as measured in the TOTEM experiment. Evaluation (using published TOTEM data) of the measured proton-proton $d\sigma/dt$ dependence on the absorptive corrections indicated that possible soft photon corrections to the hadronic amplitude slope may be essential for such data analysis.

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Unveiling the Sea: Identifying Quark Distributions in the Color Glass Condensate

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The seminal work in [1] established a transverse-momentum-dependent (TMD) factorization at low-x based on the Color Glass Condensate (CGC). The authors showed the generalized universality of small-x gluon distributions: the dipole and the Weizsäcker-Williams type. Efforts have been made to extend this factorization to next-to-leading order (NLO) and to elucidate the phenomenological consequences of saturation at colliders.

In this talk, I will show that TMD factorization also holds for low-x sea quark-initiated channels in electron-nucleus and proton-nucleus collisions [2]. I will provide explicit proof of this factorization by examining various processes in the CGC at NLO. I will highlight the role of initial and final state interactions, and the resulting process-dependent gauge link structures of these low-x sea-quark TMD distributions. I will also discuss the relative importance between gluon and sea-quark distributions at low-x for various two-particle correlation observables.

[1] F. Dominguez, C. Marquet, B-W. Xiao, and F. Yuan. Phys.Rev.D83:105005,2011
[2] P. Caucal, E. Iancu, F. Salazar, F. Yuan. [work in progress]

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Multistrange Hyperon Production on Nuclear Targets

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We consider the experimental data on yields of protons, strange Λ's, and multistrange baryons (Ξ, Ω), and antibaryons production on nuclear targets, and the experimental ratios of multistrange to strange antibaryon production, at the energy region from SPS up to LHC, and compare them to the

results of the Quark-Gluon String Model calculations. In the case of heavy nucleus collisions, the experimental dependence of the Ξ+/Λ, and, in particular, of the Ω+/Λ ratios, on the centrality of the collision, shows a manifest violation of quark combinatorial rules.

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Single diffraction and elastic scattering in proton-proton collisions with the STAR detector at RHIC

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The diffractive cross sections constitute a large fraction of the total hadronic cross section in p+p collisions. However, due to its nonperturbative nature, the understanding of the fundamental properties of these processes highly relies on experimental studies. In this talk, we will report the inclusive and identified charged-hadron spectra productions via a single diffractive (SD) process in p+p collisions at $\sqrt{s} = 200$˜GeV. We will also report on the particle ratios of $\bar{p}/p$ and K/π produced via the SD process and draw comparisons to the results from inclusive proton-proton collisions as well as theoretical model calculations.

In addition, the first measurement of the proton-proton elastic cross section at $\sqrt{s} = 510$˜GeV will be presented. The dependences of the elastic cross section on the collision energy and the momentum transfer (t) will be discussed and compared to model calculations for the relevant physics implications.

Diffraction in ep and eA / 129

Tagged Deep Inelastic Scattering: exploring meson structure functions and beyond at JLab

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The tagged deep inelastic scattering (TDIS) run-group of experiments at Jefferson Lab (JLab) will probe the mesonic content of the nucleon via the Sullivan process, in which an electron scatters from the meson cloud of the nucleon. It is a pioneering experimental program at JLab employing spectator tagging to access the Sullivan process in a high-luminosity, fixed-target experiment, enabling a unique and clean extraction of the F_2 structure functions (SF) of pions and kaons. There has been a surge of interest in the meson SFs ever since they were identified as key to mapping out the momentum dependence of the dressed quark mass and their connection to emergent hadron mass (EHM). The TDIS program is well-positioned to provide this highly anticipated new data on the meson structure in the valence regime. The status of the experiment and all the significant new developments will be discussed in this talk.

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NLO calculations for inclusive back-to-back dijet in DIS in the saturation regime

Authors: Bjoern Schenke[1]; Farid Salazar[2]; Paul Caucal[3]; Raju Venugopalan[None]; Tomasz Stebel[4]

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Advancing the understanding of the dipole picture of Deep-Inelastic Scattering (DIS) in the high energy limit has been the subject of intense investigations over the past several years. These developments have followed multiple directions, with a special emphasis on the calculation of higher order quantum corrections for several DIS processes.

In this talk, I will present a recent computation of the back-to-back dijet cross-section in DIS at small-x to next-to-leading order (NLO) in the Color Glass Condensate effective field theory [1]. The result can be factorized in terms of the Weizsäcker-Williams gluon transverse momentum dependent distribution function (WW gluon TMD) with a universal soft factor and an NLO coefficient function. The soft factor includes both double and single logarithms in the ratio of the relative transverse momentum of the dijet pair to the dijet momentum imbalance . Likewise, the WW TMD obeys a nonlinear RG equation in that is kinematically constrained to satisfy both lifetime and projectile-rapidity ordering. Exact analytical expressions are obtained for the NLO coefficient function of transversely and longitudinally polarized photons.
Finally, I will argue that in the case of a dihadron measurement (instead of dijet), the factorized expression must be amended by introducing transverse momentum dependent fragmentation functions [2].

These results allow for a quantitative separation of the dynamics of Sudakov suppression from that of gluon saturation with dijet or dihadron correlations at the future EIC.

[1] P. Caucal, F. Salazar, B. Schenke, T. Stebel, R. Venugopalan, PRL 132 (2024) 8
[2] P. Caucal, F. Salazar, arXiv:2405.19404

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Recent results from STAR for parton distribution functions at low and high x in proton-proton collisions

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Jets, clusters of collimated particles produced in high energy proton-proton (pp) collisions, serve as a useful channel for studying the internal structure of the proton. According to perturbative quantum chromodynamic (pQCD) calculations, at center-of-mass energies of $\sqrt{s}$ = 200 and 510 GeV, jet production at mid-pseudorapidity, $|\eta| < 1$, is dominated by quark-gluon and gluon-gluon scattering processes. Therefore these jets are direct probes of the gluon parton distribution functions (PDFs) with momentum fraction $0.01 < x < 0.5$. Moreover the $W^{+/-}$ boson cross-sections and their ratio, W^+/W^-, at $\sqrt{s} = 510$ GeV are effective tools to explore quark and anti-quark PDFs. In particular, the W^+/W^- cross-section ratio is sensitive to $\bar{d}/\bar{u}$. In this talk, we will present the recent STAR results of mid-pseudorapidity inclusive jet cross-sections at $\sqrt{s}$ = 200 and 510 GeV, and the W boson cross-sections and their ratio at $\sqrt{s} = 510$ GeV, from pp collisions. The theoretical implications of these results will also be discussed.

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The 3D structure of the nucleon in momentum space: TMD phenomenology

Author: Marco Radici[None]

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I will give a brief overview of our current understanding of the internal partonic 3D structure of nucleons in momentum space. I will discuss some recent extractions of Transverse-Momentum dependent Distributions (TMDs) for quarks, whose analyses are reaching a theoretical precision comparable to collinear Parton Distribution Functions (PDFs). On the contrary, gluon TMDs are poorly known from a phenomenological point of view. If I have time, I will sketch a recent model calculation covering all (un)polarized gluon TMDs at leading twist.

UPC and gamma gamma physics I / 133

Review of Monte Carlo efforts for UPC collisions

Author: Hua-Sheng Shao[1]

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In this talk, I will report the recent developments in the Monte Carlo tool gamma-UPC for the automated event generation of arbitrary exclusive final states via photon-photon fusion in ultra peripheral collisions of protons and/or nuclei, which is of relevance for novel SM measurements and BSM searches. Some examples at next-to-leading order accuracy will also be given.

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Computation of DIS diffractive structure functions

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We solve the equations for the $q\bar{q}g$ part of the DIS diffractive structure functions, proposed in arXiv:2206.13161, using quasi Monte Carlo methods, and compare to HERA data.

135

Progress in Resummed Calculations at the LHC

Author: Georgios Billis[None]

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In this talk I will provide a short overview of the resummation formalism in QCD, focusing in particular on how it is achieved with the effective field theory approach. Furthermore, I will present a

review of the state-of-the art precision predictions for the LHC for processes with a color-singlet or a color-singlet plus one jet in the final state.

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Challenging exclusive top quark pair production at low and high luminosity LHC

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We investigate the elastic production of top quark pairs ($t\bar{t}$) in pp collisions at low and high luminosities. Our study extends to the sum of two semi-exclusive $t\bar{t}$ production modes, specifically photon–Pomeron (γ–IP) and Pomeron–Pomeron (IP–IP) interactions. We consider semi-leptonic $t\bar{t}$ decay, tagging of both forward protons, and low pile-up scenarios. Our findings indicate that measuring the combined IP–IP and γ–IP contributions is feasible. However, separating individual channels becomes challenging at high luminosities. At low pile-up, the γ–IP signal can be distinguished from backgrounds, allowing us to probe the γ–IP interactions effectively.

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The experimental spin program at RHIC

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At the Relativistic Heavy Ion Collider RHIC and Brookhaven National Lab in the US, the access to the spin structure of the nucleon was one of the main goals from the inception of RHIC. Using longitudinally and polarized beams at collision energies from 62 to 510 GeV the helicity structure could be accessed. In particular the spin contribution of gluons could be obtained successfully at intermediate x using jet, dijet, pion and direct poton double spin asymmetries. Also the role of the sea quark spins could be obtained with the help of W boson production at the highest collision energies.
Transverse spin asymmetries give access to transverse momentum dependent distributions and related higher twist correlators. Both provide information about spin-orbit correlations inside the nucleon, as well as about quark transversity. Recently also the nuclear modification of transverse single spin asymmetries has been obtained in polarized proton-nucleus collisions.

The recent spin related measurements at RHIC regarding both longitudinal and transverse spin structure of the nucleon will be presented.

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RG improved JIMWLK Hamiltonian: running coupling and DGLAP evolution

Author: Michael Lublinsky[None]

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JIMWLK Hamiltonian describes energy evolution of observables
in high energy collision. It is known up to NLO accuracy. In this talk we present an RG improved Hamiltonian that incorporates DGLAP evolution and running coupling effects.

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Structures in single proton diffractive dissociatoin at the LHC

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We predict structures in t (a dip followed by a dump) in proton single diffractive dissociation for various missing masses in the LHC energy range.

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Threshold resummation for Z boson pair production

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Vector boson pair production forms an irreducible background in the Higgs boson production process. In addition, it offers an unique gateway to explore new physics searches, where it can be detected in the form of anomalous couplings. In this work, we perform threshold resummation for an on-shell Z boson pair, in the quark-antiquark annihilation channel, at NNLO+NNLL accuracy. We study invariant mass distribution at the energies of LHC and compare the soft virtual cross-section to the full fixed order result. We also give predictions for resummed invariant mass distribution, relevant for the future colliders.

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Scaling of the elastic proton-proton cross-section

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We discuss scaling properties of the elastic pp cross-section both at the ISR and the LHC. We observe that the ratio of bump to dip positions of the differential cross-section dsigma/dt is constant over the wide energy range. We next study the consequences of this property including scaling and amplitude parametrization of the scattering amplitude.

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Twist corrections to exclusive vector meson production in a saturation framework

Authors: Andrey Grabovsky[None]; Lech Szymanowski[1]; Michael Fucilla[2]; Renaud BOUSSARIE[3]; Samuel WALLON[None]

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The center-of-mass energies available at modern accelerators, such as the Large Hadron Collider (LHC), and at forthcoming generation accelerators, such as the Electron-Ion Collider (EIC), offer us a unique opportunity to investigate hadronic matter under the most extreme conditions ever reached. In particular, they allow access to the so-called Regge-Gribov (or semi-hard) limit of QCD, characterized by the scale hierarchy $\sqrt{s} \gg \{Q\} \gg \Lambda_{\rm QCD}$, where $\sqrt{s}$ is the center-of-mass energy, $\{Q\}$ a set of hard scales characterizing the process and $\Lambda_{\rm QCD}$ is the QCD mass scale. This kinematic limit is the stage where some of the most intriguing phenomena of strong interactions manifest themselves, such as the formation of a state of gluonic matter that is known under the name of color glass condensate (CGC). This state is characterized by a high-density of particles possessing a color charge (color condensate), by a slow evolution compared to the natural time of the interaction and by a disordered field distribution (properties assimilable to those of a glass). The quest for the saturation regime constitutes one of the pillars of the EIC physics program and a stimulating opportunity for the LHC experiments. In order to reveal saturation, highly accurate theoretical predictions are therefore unavoidable

In this talk, I will present the full next-to-leading order results for the cross-sections of diffractive single- or double hadron photo- or electroproduction with large p_T, on a nucleon or a nucleus and a pioneering calculation of the exclusive diffractive production of a transversely polarized light vector meson in $\gamma^* p$ collision, obtained in a framework mixing the higher-twist formalism of exclusive processes with the Balitsky shockwave effective theory of small-x physics.

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Top quark production in hadron colliders at NNLL accuracy

Author: Leszek Motyka[None]

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The soft gluon resummation technique allows for systematic improvement of fixed order calculations in QCD. In this talk it will be described how to apply this method at NNLL accuracy for processes with top quarks at hadron colliders. Furthermore, the current status of theoretical calculations of the cross sections for such processes will be presented. Particular emphasis will be placed on the

associated production of the top-antitop quark pair and a heavy gauge boson: the Higgs boson or the W,Z bosons at the NNLL accuracy. The improvement of theoretical precision due to the soft gluon resummation will be discussed in detail.

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3D structure of the nucleon and polarization effects in QCD: an introduction

Authors: Barbara Badelek[1]; Umberto D'Alesio[2]

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We will give a short introduction on the importance of the study of the three-dimensional structure of the nucleon and polarization effects in QCD. The main quantities, like TMDs and GPDs, as well as the observables relevant in this context will be presented.

UPC and gamma gamma physics III / 145

Collectivity in Ultraperipheral Heavy Ion Collisions and e+A Collisions

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High energy Heavy Ion Collisions produce a hot and dense medium that shows clear signals of collectivity consistent with a strongly interacting final state and production of the quark gluon plasma. Smaller collision systems, such as p+A collisions show similar signals. At the Large Hadron Collider, ultraperipheral Pb+Pb collisions, which are essentially photon+lead collisions, also show a large momentum anisotropy reminiscent of collective effects. This talk will review various interpretations of such signals, including the final state interpretation using hydrodynamics, as well as initial state effects from the color glass condensate.

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Recent results from HERA experiments H1 and ZEUS

Author: Mariusz Przybycien[1]

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Though taking of the new data in the H1 and ZEUS experiments at HERA finished in 2007, their analysis is still ongoing, and new results are being published. In this talk, we will present the most recent results obtained from the two experiments. A new measurement of inclusive-jet cross sections in the˜Breit frame and the azimuthal correlation between the leading jet and the scattered lepton in

NC DIS will be presented. Also, the differential cross-section measurement of NC DIS events with an empty hemisphere in the Breit frame, the 1-jettiness event shape observable τ_1^b and the first measurement of groomed event shape observables in DIS will be discussed.

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Diffractive dijets at HERA and EIC using GTMDs

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We calculate differential distributions for
diffractive dijets production in $ep \to e'pjetjet$
using off diagonal unintegrated gluon distributions (GTMDs).
Different models are used.
We concentrate on the contribution of exclusive $q\bar{q}$ dijets.

Results of our calculations are compared to H1 and ZEUS data.
In general, except of one GTMD, our results are below the HERA data.
This is in contrast to recent results where
the normalization was adjusted to some selected distributions
and no agreement with other observables was checked.
We conclude that the calculated cross sections are only a small part
of the measured ones which contain probably also processes
with pomeron remnant.

We present also azimuthal correlations between the sum
and the difference of dijet transverse momenta.
The cuts on transverse momenta of jets generate
azimuthal correlations which can be misinterpreted.

We also present our predictions for EIC.

The presentation will be based on:\\

B. Linek, M. Luszczak, W. Sch\"afer and A. Szczurek.
arXiv: 2403.15110.

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Collectivity probes in small systems and photoproduction studies at the LHC

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Since the discovery of collectivity signatures in proton-proton collisions in 2010 at the LHC, the interest to probe the limits of such effects in the smaller systems with lower multi parton interactions has increased up to date. This talk discusses recent probes and studies for collectivity including intrajet and diffractive interactions. Searches and angular studies within quark-antiquark and mesons photoproduction that take place in single diffractive and exclusive collisions with forward features, which will be also discussed.

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Calculation of the Quasi-Two-Body $B_s^0 \to D_{s1}(2536)^- K^+ [D_{s1}(2536)^- \to \bar{D}^*(2007)^0 K^-]$ Decay

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The decay $B_s^0 \to D_{s1}(2536)^- K^+$ was recently observed for the first time and its branching fraction was measured using a data sample corresponding to an integrated luminosity of 9 fb^{-1} of pp collisions collected by the LHCb experiment with the significance for the B_s^0 signals larger than 10σ.
The product of branching fraction is measured by LHCb collaboration to be
$\mathcal{B}(B_s^0 \to D_{s1}(2536)^- K^+) \times \mathcal{B}(D_{s1}(2536)^- \to \bar{D}^*(2007)^0 K^-)$
$= (2.49 \pm 0.11 \pm 0.12 \pm 0.25 \pm 0.06) \times 10^{-5}$.

In this study we have calculated the branching fraction of the $B_s^0 \to D_{s1}(2536)^- K^+ [D_{s1}(2536)^- \to \bar{D}^*(2007)^0 K^-]$ quasi-two-body decay. It is known that in the narrow width approximation the 3-body decay rate obeys the factorization relation as
$\mathcal{B}(B_s^0 \to D_{s1}(2536)^- K^+ \to \bar{D}^*(2007)^0 K^- K^+)$
$= \mathcal{B}(B_s^0 \to D_{s1}(2536)^- K^+) \times \mathcal{B}(D_{s1}(2536)^- \to \bar{D}^*(2007)^0 K^-)$.

We have estimated the branching ratio of the $B_s^0 \to D_{s1}(2536)^- K^+$ and $D_{s1}(2536)^- \to \bar{D}^*(2007)^0 K^-$ decays by using the Feynman quark diagrams, we have obtained
$\mathcal{B}(B_s^0 \to D_{s1}(2536)^- K^+) \times \mathcal{B}(D_{s1}(2536)^- \to \bar{D}^*(2007)^0 K^-) = (2.18 \pm 0.37) \times 10^{-5}$.

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The SuperChic Monte Carlo Generator: New Developments

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I present recent developments in the SuperChic Monte Carlo Generator for central exclusive production processes.

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Experimental Spin Program at Jefferson Lab

Author: Jian-Ping Chen[None]

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High performance polarized beam and targets at Jefferson Lab enabled an extensive program to measure nucleon spin structure functions with high precision. This talk will highlight the recent JLab spin experiments, including the measurement of the spin asymmetry (A1) in the high-x region and the measurement of the spin moment d2 in medium-high Q2 region to study quark-gluon correlations. Recent results on spin moments at low Q2 (spin sum rules and spin polarizabilities) will also be presented. Outlook for future will be discussed.

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J/Ψ Photoproduction Distributions in Distinct Collision Geometries

Author: Maria Beatriz De Leone Gay[1]

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The photoproduction of J/Ψ is investigated in the coherent and incoherent collisions at LHC energy ($\sqrt{s}$ = 5.02 TeV), in distinct collision geometries: ultra-peripheral collisions (UPC) and peripheral collisions across different centrality intervals. UPC collisions were computed using a direct application of the convolution between the photon flux and the photonuclear cross section. For the peripheral regime, different centrality classes were tested (30%-50%, 50%-70%, and 70%-90%) considering an effective photon flux that only those photons reaching the geometrical region of the nuclei-target are considered. Additionally, an effective photonuclear cross section was applied. For all collision geometries, three dipole models, suited for saturation, were evaluated: the GBW, the CGC (or IIM) and bCGC (which incorporates b dependence into the CGC model). Results are presented in terms of both rapidity distribution and transverse momentum distribution, compared with ALICE data.

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The next-to-leading order Higgs impact factor at finite top-mass at the NLO: the real corrections

Author: Gabriele Gatto[None]

Corresponding Author: gabriele.gatto@unical.it

This work focuses on the production of a forward Higgs boson in high-energy proton-proton collisions, retaining full top-mass dependence. In the semi-hard regime, where the center-of-mass energy is large compared to the Higgs transverse mass, we utilize the hybrid high-energy and collinear factorization, where the Balitsky-Fadin-Kuraev-Lipatov approach, employed to resum large energy logarithms at next-to-leading order, is consistently embodied in the standard collinear picture. We present the computation of the real corrections to the singly off-shell emission function (also known as impact factor) for forward-Higgs production, maintaining full top-mass dependence.

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Studies in ultraperipheral collisions at LHCb

Author: Keri Vos[1]

[1] *Nikhef National institute for subatomic physics (NL)*

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Peripheral and ultra-peripheral heavy-ion collisions are sensitive to photon-photon and photon-nucleus interactions, revealing details about the partonic structure of nuclei and the mechanisms of vector meson production. We will discuss measurements performed by the LHCb experiment including the coherent and incoherent production of J/ψ mesons in peripheral and ultra-peripheral collisions in PbPb. Additionally, we will discuss prospects for future ultra-peripheral collision (UPC) measurements with the LHCb detector in Run 3.
Tracks: “Ultraperipheral collisions and gamma-gamma physics

Low x, PDFs and saturation I / 156

Studies of low-x physics at LHCb

Author: Keri Vos[1]

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The LHCb detector, with its forward rapidity coverage, is able to probe kinematic regions at low Bjorken-x as low as 1e-6. This unique capability, combined with excellent momentum resolution, vertex reconstruction, and particle identification, enables precision measurements at low transverse momentum and forward rapidity. Recent studies of vector boson and hadron production in proton-proton and proton-lead collisions will be presented. Z boson events are used to probe the proton structure, while charged and neutral hadron production allows the exploration of the relatively unknown low-x region. Additionally, the production of neutral pions and Dˆ0 mesons in lead-lead collisions will be discussed. Future prospects for further investigations into low-x phenomena with the LHCb detector in Run 3 are also explored.
Tracks: “Low x, PDFs, and saturation

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Dipole approach to exclusive J/\psi photoproduction and the putative gluon shadowing

Author: Wolfgang Schaefer[None]

Co-author: Agnieszka Łuszczak [1]

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We discuss the role of $c\bar{c}g$-Fock states in the diffractive photoproduction
of J/ψ-mesons as probed in ultraperipheral nuclear collisions. We build on our earlier description of the process
in the color-dipole approach, where we took into account the rescattering of
$c\bar{c}$ pairs using a Glauber-Gribov form of the dipole-nucleus amplitude.
We compare the results of our calculations to recent data on the
photoproduction of J/ψ by the ALICE, CMS and LHCb collabo
rations. We also comment on the possible relation to gluon shadowing and compare to data on the ratio $R_g = \sqrt{\sigma(\gamma A \to J/\psi A)/\sigma_{\rm IA.}}$, where $\sigma_{\rm IA}$ is the result in impulse approximation.

Based on preprint to appear and submitted to arXiv on 14. June 2024

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Central Exclusive Production with the STAR detector at RHIC

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The Central Exclusive Production (CEP) processes with Double Pomeron Exchange (DPE) in p+p collisions are particularly intriguing as they can generate h^+h^- pairs with an even spin and positive parity. This unique characteristic makes them an ideal environment for the exploration and discovery of glueball states. In this talk, we will present results on CEP of charged hadron pairs $h^+h^-(h = \pi, K, p)$ measured with the STAR experiment at RHIC in proton-proton collisions at $\sqrt{s} = 200$ GeV and 510 GeV. The differential fiducial cross sections at $\sqrt{s} = 200$ GeV will be presented and compared to the theoretical calculations from DPE models. Structures observed in the mass spectra of $\pi^+\pi^-$ and K^+K^- pairs were found consistent with the DPE model, while angular distributions of pions suggested a dominant spin-0 contribution to $\pi^+\pi^-$ production. We also present preliminary results on the measurement of the same physics process at higher $\sqrt{s} = 510$ GeV.

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Isolated gauge boson production in pp collisions at forward rapidities

Author: Yan Bandeira[1]

Co-authors: Victor Gonçalves [2]; Wolfgang Schäfer [3]

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The particle production at forward rapidities in hadronic collisions is one of the most promising processes to probe the QCD dynamics at small - x as well as to observe the breakdown of the collinear and k_T factorization theorems, predicted to occur to high partonic densities. In this process, one interacts with projectile partons with large cone momentum fractions and target partons carrying a very small momentum fraction. Thus, the projectile parton scatters off a dense gluonic system in the target. In this contribution, we investigate the case where one of the particles in the final state is an electroweak gauge boson ($G = W^{\pm}, Z^0, \gamma$) and present the differential cross-section for the isolated gauge boson production in pp collisions at forward rapidities as a function of the dipole - proton cross-section or the unintegrated gluon distribution, which can be used to estimate the impact of the saturation effects in the gauge boson production at the LHC and future colliders. Moreover, we demonstrate that our general parton-level cross-section reduces to expressions previously used in the literature for the description of the real photon production and Drell - Yan process at forward rapidities in some particular limits.

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Multiple soft emissions in QCD hard scattering

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We consider the radiation of three soft partons (three gluons or a gluon-quark-antiquark) in a generic process for multiparton hard scattering in QCD. We compute the corresponding tree-level currents from both massless and massive hard partons. We compute the soft behaviour of squared amplitudes and the colour correlations produced by the squared current. Triple soft-gluon radiation produces colour quadrupole correlations between the hard partons, while g-q-qbar entails colour tripoles. We examine the soft and collinear singularities of the squared current in various energy ordered and angular ordered regions.Colour quadrupole interactions break the Casimir scaling symmetry between quarks and gluons.

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Double gap events in ALICE Run 3

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I intend to show some results on the analysis of double gap
events in pp collisions ALICE Run 3. I will update title and content of my
talk once cleared by ALICE.

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TOTEM: Pomeron and Odderon exchange at LHC energies

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The TOTEM experiment at CERNs Large Hadron Collider (LHC) has been the leading forward physics experiment at the LHC. TOTEM has studied proton-proton (pp) elastic scattering over a wide range of four-momentum transfer t, measured the pp total cross section at several LHC energies and investigated diffractive processes in pp collision in detail together with the CMS experiment. One of the key physics motivations has been to study processes with Pomeron and Odderon exchange, i.e. exchange of charge parity even and odd colourless gluonic compounds, at LHC energies.

The talk will review the most important TOTEM physics measurements related to Pomeron and Odderon exchange. The focus will be on the recent publications on the precision study of Pomeron exchange in central exclusive dipion production at $\sqrt{s}$ = 13 TeV, and on the observation of Odderon exchange in elastic scattering from the comparison of the elastic pp and proton-antiproton cross sections at $\sqrt{s}$ = 1.96 TeV combined with the measurements of the ρ parameter and total cross section at LHC energies.

Diffraction in ep and eA / 163

Experimental prospects for exclusive/diffractive physics at ePIC

Author: Alexander Jentsch[1]

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The Electron-Ion Collider (EIC) will afford the opportunity to drastically advance our understanding of QCD and the multidimensional structure of both protons and nuclei. An essential component of the EIC physics program is the measurement and study of exclusive and diffractive final states, which yield insight into topics including partonic imaging, structure functions, proton spin, and saturation. The EIC Yellow Report provided a comprehensive look at the exclusive physics program, and several studies have been published since the Yellow Report detailing the experimental needs for these measurements. The EIC project detector, ePIC, is designed to be a nearly hermitic collider detector to meet the needs of the EIC physics program.

The primary challenge for these final states is measuring the all of the particles they produce, the most-challenging of which are near-collinear with the outgoing hadron beam and often cannot be seen by the central detectors of ePIC. It is therefore important to use subsystems integrated with the outgoing hadron beam-line, the so-called "far-forward"detectors. The ePIC experiment includes a suite of far-forward detectors designed to deliver the necessary geometric coverage and resolution required to achieve the full exclusive physics program envisioned at the EIC. In this presentation the exclusive and diffractive physics program of the EIC will be discussed and the experimental prospects using detailed detector simulations with the ePIC detector will be presented.

Low x, PDFs and saturation I / 164

Small-x phenomenology in collinear factorisation

Author: Federico Silvetti[None]

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High-energy (or small-x) logarithms are enhanced in proton scattering processes when the collider centre-of-mass energy is much larger than the hard scattering scale. In the picture of collinear factorisation, their resummation affects QCD cross-sections and DGLAP evolution kernels. In recent years, it was shown that small-x resummed theory can be used to improve predictions for Parton Distribution Function (PDF) fitting as well as parton level cross-section studied at the LHC (namely single-Higgs and heavy-quark pair production). Thus, in this talk, I will review recent results obtained with the small-x improved collinear factorisation as well as illustrate ongoing research.

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Signature of the Odderon in DIS: exclusive productions of chi_c charmonia

Authors: Abhiram Kaushik[None]; Adrian Dumitru[None]; Leszek Motyka[None]; Sanjin Benić[None]; Tomasz Stebel[1]

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Exclusive chi_c production in DIS is sensitive to the C-odd colorless tri-gluon correlation in the t-channel - the long sought Odderon. While the non-perturbative C-odd compound has been recently discovered in hadronic collisions [1], however, so far it escaped direct detections at HERA. In [2] we performed a computation of the chi_c exclusive production that takes into account the interference with the Primakoff (photon exchange). Our results reveal that Odderon dominates the moderate to

high momentum transfer region. The high luminosity of the EIC counteracts the feeble Odderon amplitude and we find a dozen of events per month. The excess above the Primakoff background as well as the characeristically slow falling t-distribution would serve as a direct signature of the Odderon at the EIC.

[1] TOTEM, Eur. Phys. J. C 80, 91 (2020); D0, Phys. Rev. D 86, 012009 (2012)
[2] S. Benic, A. Dumitru, A. Kaushik, L. Motyka, T. Stebel, 2402.19134v1 (accepted in PRD)

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Overview of the spin programme of COMPASS

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The purpose of the COMPASS facility is a study of hadron structure and spectroscopy with high energy hadron and (polarised) muon beams. In the spin programme polarised proton and deuteron targets were used in inclusive and semi-inclusive deep-inelastic reactions as well as in the Drell-Yan process. Deeply virtual Compton scattering and hard exclusive meson muoproduction were studied using an unpolarised proton target.

A panorama of COMPASS results on 1D and 3D nucleon structure will be presented.

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Tagging nucleons in proton-Oxygen collisions at the LHC

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A short run of proton-oxygen (pO) collisions is planned at the Large Hadron Collider (LHC) at CERN in 2025 to improve the modeling of air showers, which are described using hadronic Monte Carlo simulations. A very forward proton and neutron detectors introduced by the ATLAS and the CMS experiments could provide a unique opportunity to study elastic and diffractive interactions in pO collisions for the first time at the center of mass energies above TeV. In my talk, I will present the impact of proton and neutron tagging on the measurement of the elastic and diffractive components and discuss the perspectives of measuring decay products of oxygen ions after dissociation.

Hadroniic final state I / 170

Jet and jet substructure: ALICE results (on behalf of the ALICE Collaboration)

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Jets and their substructure in pp collisions offer a unique opportunity to probe various aspects of quantum chromodynamics (QCD), ranging from perturbative QCD tests to the study of non-perturbative phenomena such as hadronization. They also probe the transition between perturbative and non-perturbative regimes. In heavy-ion collisions, jets serve as a novel tool to investigate the microscopic properties of the deconfined quark-gluon plasma (QGP). Recently, significant progress has been made in developing jet substructure observables to explore these properties. The ALICE experiment is particularly well-suited for jet measurements due to its advanced high-precision tracking system, which is especially beneficial for detecting low transverse momentum jets.

This talk will highlight recent ALICE measurements of inclusive and semi-inclusive jets, along with various jet substructure observables in both pp and Pb-Pb collisions. These substructure studies encompass the jet Lund plane map, jet angularities, groomed jet momentum fraction, groomed jet radius, number of soft drop splittings, subjet fragmentation functions, and two-point energy correlator. The comparisons between data and predictions from Monte Carlo (MC) models as well as analytical calculations will be discussed.

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First measurement of the D^0 production in photonuclear ultra-peripheral heavy -ion collisions with CMS

Author: Gian Michele Innocenti[1]

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The study of heavy-quark photoproduction in ultraperipheral collisions (UPC) of heavy ions provides a new tool to characterize the production mechanisms of heavy-quarks with high experimental and theoretical control, and constrain the properties of nuclear matter in a wide region of the (x, Q^2) with perturbatively-produced hard probes. In this talk, we will present the first measurement of the production yield of D^0 mesons as a function of their transverse momentum and rapidity performed in ultra-peripheral PbPb collisions at 5.36 TeV, performed by CMS using the first heavy-ion data from the LHC Run 3. The results will be compared to recent calculations that describe the production of charm photoproduction in UPC and exploit different modeling of the nuclear parton distribution functions (nPDFs). These results will provide new insights into the nuclear parton distribution functions of gluons down to low x and Q^2 and pave the way for high-accuracy measurements of the heavy-quark production and shower evolution in the clean experimental environment that characterized photonuclear collisions.

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Collective properties of the nuclear matter at RHIC

Author: Sonia Kabana[1]

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Flow harmonics provide valuable informations unravelling the dynamics and the properties of dense and hot nuclear matter and of the Quark-Gluon Plasma (QGP) medium expected to be produced in heavy-ion collisions at ultrarelativistic energies. We will present recent results on the directed flow

(v1), elliptic flow (v2) and other flow harmonics of hadrons produced in nucleus nucleus collisions at top energies and in the beam energy scan, measured by the experiments at the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory in USA and we will discuss what can we learn from these results in the light of model calculations.

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Photoproduction of coherent quarkonia in heavy ion collisions

Author: Luis Alcerro Alcerro[1]

[1] *The University of Kansas (US)*

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The quasi-real photons surrounding ions in ultraperipheral collisions are privileged probes to understand the gluonic nuclear structure. In particular, the coherent photoproduction of heavy quarkonia are processes sensitive to the gluon distribution of the target nucleus, especially at the low Bjorken-x region where the QCD gluon saturation regime is expected to be found. In addition, the heavy quark masses set a sufficiently large scale for an interpretation in terms of perturbative QCD calculations. Moreover, the distinct masses provide valuable and complementary information. We will present recent CMS results on exclusive coherent quarkonia photoproduction in heavy ion collisions.

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Electroweak and BSM prospects with ePIC

Author: Michael Nycz[None]

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The central focus of the future Electron Ion Collider (EIC) and the planned ePIC detector has been to address fundamental questions in Quantum Chromodynamics (QCD). Importantly, with the high luminosity and polarized electron and ion beams along with the wide kinematic coverage of the ePIC detector, the EIC can provide a unique opportunity to study both electroweak (EW) and Beyond the Standard Model (BSM) physics. In this talk I will outline the experimental prospects for BSM and EW physics, including topics such as Parity-Violating Deep Inelastic Scattering (PVDIS) and Charge Lepton Flavor Violation.

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Online and Offline Event selections for UPC heavy-flavor and jet events with CMS

Author: Balazs Kovacs[1]

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The CMS experiment has designed and deployed a new trigger strategy for the recent heavy-ion of Fall/Winter 2023 to maximize the statistics of photon-nuclear and photon-photon collisions in ultra-peripheral (UPC) heavy-ion collisions. For this purpose, the Zero-Degree Calometers (ZDCs)

have been fully integrated into the Level-1 triggering system of CMS for the first time. New trigger algorithms have been designed and deployed to collect heavy-flavor and jets UPC events based on the information from the Zero-Degree Calometers (ZDCs) and the HCAL and ECAL calorimeters. In this poster, we will present the key aspects of this new trigger strategy and the strategy developed to suppress background events in the offline analysis. One of the main challenges of UPC photonuclear analysis is, indeed, the rejection of hadronic events and beam-gas or machine-induced background. A specific focus will be given to the optimization of the rapidity gap selections in combination with the requirements on the number of detected neutrons in the ZDCs.

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Overview of the latest ALICE UPC and photonuclear results

Author: Simone Ragoni[1]

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Ultra-peripheral collisions (UPC) are events characterised by large impact parameters between the two projectiles, larger than the sum of their radii. In UPCs, the protons and ions accelerated by the LHC do not interact via the strong interaction and can be regarded as sources of quasireal photons.

Using the Run 2 data, the ALICE Collaboration has carried out various measurements of different final state systems, such as exclusive four pion photoproduction as well as photoproduction of K^+K^- pairs, measured for the first time in ultra-peripheral collisions. In addition, vector meson production in Pb–Pb provides the unique opportunity to carry out an analogy of the double-slit experiment at femto scales, owing to the interference between the production sources of the two lead nuclei. These results and prospects for UPC measurements using Run 3 data will be presented.

UPC and gamma gamma physics II / **177**

Overview of the latest ATLAS UPC+photonuclear results

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Overview of the latest ATLAS and ATLAS-AFP photoproduction results

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Latest UPC Results from STAR

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Relativistic heavy ion collisions generate intense electromagnetic fields, enabling the study of photon-induced interactions. These phenomena are typically examined in ultra-peripheral collisions (UPCs) of relativistic heavy ions. UPCs facilitate the production of di-lepton and di-hadron pairs through γ + γ interactions, as well as vector mesons via γ + A interactions. The resulting photon produced vector mesons and lepton/hadron pairs inherently carry the characteristics of the originating electromagnetic fields. Moreover, photon-produced vector mesons serve as probes for the gluon distribution within the target nucleus. This distinction can be seen in coherent production, which involves the entire nucleus, and incoherent production, which involves individual nucleons. In this presentation, we will delve into recent results from the STAR experiment, focusing on vector mesons, di-lepton pairs, and di-hadron photoproduction. These measurements will be compared to theoretical model predictions to elucidate their implications and enhance our understanding of photon induced interactions in heavy ion collisions

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Unexpected breakdown of collinear factorisation at leading twist in exclusive $\pi^0 - \gamma$ photoproduction due to Glauber pinch

Author: Samuel WALLON[None]

Co-authors: Jakob Schoenleber ; Lech Szymanowski [1]; Saad Nabeebaccus [2]

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In this talk, we will present our finding of the breakdown of collinear factorisation, for the very first time in the case of an exclusive process, here for the exclusive photoproduction of a $\pi^0\gamma$ pair. Such a process is sensitive to both quark and gluon GPD channels. In the latter case, the amplitude fails to factorise, due to the presence of a Glauber pinch, which has the same power counting as the standard non-divergent collinear pinch. The Glauber pinch that occurs here is peculiar, since the mechanism that produces it involves two loop integrals. This is corroborated by an explicit calculation of the gluon GPD channel to pair photoproduction, which leads to a divergent amplitude already at leading twist-2 and at leading order in α_s. Such collinear factorisation breaking effects also occur in similar processes, such as the crossed channel of $\pi^0 N \to \gamma\gamma N$ scattering for the same reason. On the other hand, for processes where the gluon GPD channel is forbidden, which correspond to the case where the outgoing meson is a charged pion or a rho meson, collinear factorisation works without any issues.

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Jet and jet substructure

Author: CMS Coll[None]

This talk will present the jet and jet substructure results from the CMS and ATLAS experiments, including the Lund jet plane analysis.

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Diffractive results from CMS

Author: Istvan Szanyi[1]

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We present the different results on diffraction from CMS and TOTEM, namely diffractive jet production, jet gap jet...

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Recent Results from PPS and prospects

Author: CMS Coll[None]

We present the PPS detector and the most recent physics results

Low x, PDFs and saturation I / 187

Recent results relevant for PDFs at low and high x, saturation in pp and HI collisions

Author: Georgios Krintiras[1]

[1] *The University of Kansas (US)*

We discuss the results relevant to PDF determination at low and high x, including the nuclear PDFs

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Modifed homotopy approach for diffractive production in the saturation region

Author: Carlos Contreras[None]

Co-authors: Eugene Levin ; Jose Garrido ; Rodrigo Meneses

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We present our results from homotopic method [1] for solving of the non linear evolution equation for the diffractive production in deep inelastic scattering (DIS). We introduce the nonlinear corrections part as a first step of this approach. This simplified nonlinear evolution equation is solved analytically taking into account the initial and boundary conditions for the process. It turns out that these corrections are rather small and can be estimated in the regular iterative procedure [2].
References:
[1] C. Contreras, J. garrido, E. Levin and R. Meneses: Phys. Rev. D 107 (2023) 9, 094030. arXiv 2302.10497[hep-ph]
[2] C. Contreras, J. Garrido, E. Levin and R. Meneses: arXiv 2406.11673 [hep-ph]

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Vector boson production in association with jets ATLAS+CMS (including HF jets)

Author: Giovanni Padovano[1]

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NLO impact-factor for the forward eta_c meson production

Author: Maxim Nefedov[1]

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Combining the recently-computed one-loop corrections [1] for $g + R- > c\bar{c}[^1S_0^{[1]}]$ impact factor(IF), and the corresponding real-emission corrections, the complete NLO IF for the eta_c meson production at forward rapidities is computed. Results in several schemes for regularisation of rapidity divergence are presented: the tilted Wilson line scheme, the BFKL scheme (for computation of pair-production-type observables, with large rapidity separation between components of the pair) and in the High-Energy-Factorisation scheme (for the NLL resummation of partonic high-energy logarithms).

[1] M.˜Nefedov,
%“On the high-energy instability of quarkonium production,”
Nucl. Part. Phys. Proc. \textbf{343}, 11-16 (2024)
doi:10.1016/j.nuclphysbps.2023.11.012
[arXiv:2309.09608 [hep-ph]].

Low x, PDFs and saturation I / 191

Recent ALICE results relevant for PDFs at low and high x, saturation

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CMS-PPS2 at HL-LHC

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During the upcoming 'LHC Long Shutdown 3', the presently installed Proton Precision Spectrometer (CMS-PPS) will be
adopted to the requirements of High Lumi LHC. The acceptance, mass range and the technological challenges of this new
spectrometer will be presented.

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Computation of integral and space-time structure of luminosity at a collider

Author: Joachim Baechler[1]

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The knowledge of the integral and space-time structure of luminosity are key for collider experiments.
The new algorithm ILUMI4d allows to compute for arbitrary beam parameter settings, the luminosity of a single bunch crossing and the 3d interaction vertex distribution as function of the bunch crossing time. The performance of the algorithm will be demonstrated with different beam parameter settings.

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ATLAS results on diffraction

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We will present the most recent results from ATLAS on diffraction.

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Forward detectors in ATLAS and physics results

Author: Maciej Piotr Lewicki[1]

[1] *Polish Academy of Sciences (PL)*

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We will present the most recent results from the forward detectors in atlas.

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Vector boson production in association with jets (ATLAS+CMS)

Author: Giovanni Padovano[1]

[1] *Sapienza Universita e INFN, Roma I (IT)*

We will present the most recent results on vector boson production with jets (including heavy flavor) from CMS and ATLAS

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Overview of the latest CMS UPC and photonuclear results

Author: Luis Alcerro Alcerro[1]

[1] *The University of Kansas (US)*

Corresponding Author: l.alcerro@cern.ch

We present the recent results from CMS about UPC and photon-nuclear interactions in heavy ion.

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Welcome

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Low x, PDFs and saturation I / 200

Recent results relevant for PDFs at low and high x, saturation in pp and HI collisions from CMS (187)

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Low x, PDFs and saturation I / 201

Recent ALICE results relevant for PDFs at low and high x, saturation (191)

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Low x, PDFs and saturation I / 202

Small-x phenomenology in collinear factorisation (164)

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Heavy flavored mesons produced with high p_T demonstrate specific features of the production mechanism, such as: (i) short time of gluon radiation by a highly virtual heavy quark; (ii) short formation time of the heavy flavored meson wave function; (iii) enhancement of the fragmentation function $D_{b/B}(z)$ at large fractional momenta $z \to 1$; (iv) short mean free path in the medium (no color transparency). In particular these features explain the observed very different p_T dependences of the nuclear ratio R_{AA} for J/ψ produced directly and indirectly (from B-decays). Data for D-meson production are explained as well.

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