Třetí miniworkshop difrakce a ultraperiferálních srážek

Anotace prezentovaných příspěvků

1 Session 1

1.1 Introduction to the workshop

Guillermo Contreras

A brief overview of the spirit of the meeting and the motivation of our different activities is presented. In particular, it is stressed that all activities—detector construction, analyses of experimental data, and computation of theoretical predictions as well as development of phenomenological models—are united by our quest to understand QCD in the high-energy limit.

1.2 Introduction to dark matter

Guillermo Contreras

In order to get a broader view of science and to have a deeper development as physicists, it is useful for the students to keep abreast of the most important developments in other areas of knowledge. In this case we present an overview of the current status of searches for dark matter. First, the arguments why we think that most of the matter in the universe is dark, and unknown to us, are discuss. Emphasis is placed on spelling out the assumptions behind our theories and presenting potential alternative routes to explain the observations. Then the most recents searches for dark matter in experiments similar to those used by us are presented and discussed.

1.3 Dark matter plans in Zurich

Marek Matas

In this talk, I have discussed the history of the search for dark matter and understanding of its origin.

I have discussed its discovery by Fritz Zwicky and how the perception of this elusive phenomenon has been changing over the course of the past few decades. Outlined several dark matter candidates that were some of the most promising theories that could explain the origin of dark matter including the so-called WIMPs (weakly interacting massive particles).

I have put emphasis on how my future career at the ETH will be focused on finding a way of measuring the presence of dark matter particles through direct detection with electrons in solids. This search will aim for weakly interacting particles, namely those that are reportedly detected by the DAMA experiments.

2 Session 2

2.1 Intro to the FDD

Guillermo Contreras

The Forward Diffraction Detector is a project where our group is strongly involved. We present the general idea of the detector as well as the physics and technical objectives we want to achieve with it. The presentation is followed by a hands-on session where a prototype of one of the modules of the detector is built.

2.2 The construction of FDD: hands on!

Solangel Rojas and Vojtěch Zabloudil

During the ongoing Long Shutdown 2 of the LHC, ALICE (A Large Ion Collider Experiment) is implementing a significant upgrade of its systems to cope the conditions expected during the Run 2 and 3 of the LHC. The Fast Interaction Trigger (FIT) will provide the minimum latency interaction trigger, luminosity monitoring, precision collision time, and determination of centrality and event plane for heavy-ion collisions. FIT consists of three subsystems:FV0, FT0 and FDD, which are the upgrades of the V0, T0 and Alice Diffractive (AD) detectors, respectively. The three subdetectors will be placed in the forward regions with respect to the interaction point.

In particular, the FDD detector consists of two stations covering the pseudorapidity ranges of $4.7 < \eta < 6.3$ and $6.9 < \eta < 4.9$, respectively. This coverage allows FDD to tag diffractive and ultra-peripheral events efficiently. The stations are made of two layers of plastic scintillators, divided into four quadrants. Each quadrant has two wavelength shifting (WLS) bars connected to individual PMTs via a bundle of clear optical fibres. Among the main improvements of the FDD, with respect to the AD, are faster plastic scintillators and WLS, and the use of the newly developed front-end electronics suitable for operation both in a triggered and in a continuous readout mode. The FDD will ensure that ALICE has the large pseudorapidity coverage needed to (1) select diffractive events down to diffractive masses of a few GeV/c^2, and (2) to veto particle production in the forward regions to obtain clean samples of ultra-peripheral events.

During this introduction and miniworkshop we showed the ingredients and steps for the construction of one FDD detector pad, which consists into assembly the main sensitive pad to the particles produced during the collision in the ALICE interaction point. The audience was able to see the real detector closely

and manipulate the parts of a real detector. After this, two volunteers were able to construct one module using spare pieces of AD detector.

3 Session 3

3.1 The Muon Forward Tracker (MFT)

Katarína Křížková Gajdošová

The operation of the Large Hadron Collider (LHC) is divided into several years of running, which are followed by periods called Long Shutdown dedicated to maintenance and upgrade. During the Long Shutdown 2 (LS2), which is happenning now, the ALICE experiment will undergo significant changes in both hardware and software section. One of the affected detector subsystems of ALICE is the Muon spectrometer. Its performance will be greatly enhancd by a new detector, the Muon Forward Tracker (MFT), which will start its operation after the LS2.

The main motivation for building the MFT lies in the heavy flavor sector. In particular, it will improve the determination of the production vertex and tracking. We will be able to measure muon offset at primary vertex, which will allow us to separate muons from open charm or open beauty decays. Furthermore, thanks to the MFT we will be able to measure secondary vertices of decaying particles, which will help us to discriminate prompt J/Ψ and J/Ψ coming from B decays.

The MFT has full azimuthal coverage, and spans -3.6 $< \eta <$ -2.45 in pseudorapidity. It consists of 5 disks, each with 2 faces. On each face there are ladders with 2-5 sensors, the ALPIDE silicon pixels of 0.4 m^2 size. The whole MFT will contain 936 sensors.

The MFT is now assembled, and is being tested at CERN. The estimated time for commissioning in the cavern is summer 2021.

3.2 MFT: construction, commisioning

Diana Krupová

Muon Forward Tracker (MFT) was designed to add precise vertexing capabilities to muon tracking at forward rapidities. The MFT detector incorporates ALPIDE silicon chips assembled in ladders. After the assembly, the ladders are tested and qualified according to a specific procedure. One of the goals is to obtain a uniform threshold: to find the suitable operating point for each chip, a process called threshold tuning is used. Another crucial tool in ladder qualification process is the eye measurement, performed in order to test signal strength and stability. After gluing the ladders to the half-disks, the qualification procedure is repeated.

The results of the tests were analysed to describe the detector behaviour, which has proven the detector to have uniform threshold with low noise, low occupancy rate and only a small fraction of dead or inefficient pixels. This makes

the detector suitable for providing interesting results for vertexing or tracking down to low p_T.

3.3 QC for the MFT

Tomáš Herman

Quality control (QC) software plays a crucial role during data taking at the LHC and ALICE as it monitors any potential problems with the detector or its associated electronics thus making sure that the measured data is of good quality for physics analysis. For Run 3 in ALICE a new QC system is being developed as a part of the O2 framework. The QC has two components, first is a fast-online part for immediate monitoring of the data and second is an offline post-processing part for monitoring of long-term effect. For both time scales there are automatic preprogramed checks and a human shifter will be monitoring the output histograms during the data taking.

The QC chain starts with a data producer which will be the detector during data taking and, in the meantime, it is a Monte Carlo generated data set. The read-out data is sampled to monitor only part of it as the available computational power is limited and the data stream during the Run 3 will be enormous. Next, the QC Task processes the data and creates monitoring objects which are periodically checked and published to the database and displayed in a browser GUI.

For the Muon Forward Tracker (MFT) there are five disks subdivided into half disks, zones and ladders all composed of silicon pixel chip sensors. There are 936 chips further subdivided into regions and double columns all consisting of about 500 million pixels. All these hardware objects have to be monitored in the QC. Furthermore, the monitoring is done for several software objects: readout information, digits, clusters, MFT tracks, MFT+MUON tracks, physics and calibration. The basic objects of the QC for MFT are currently 2D pixel hit maps for all 936 chips. These provide access to pixels, double columns and regions. From the 2D hit maps are extracted chip occupancies displayed in a layout of the half disk which allow access to chips, ladders and zones.

First tests focusing on finding very hot pixels are using the standard deviation of the 2D hit maps to find the problematic chips. The method seems promising and further test are ongoing.

3.4 $\mathbf{n^{O}_{O}n}$

Michal Broz

The study of photon-induced reactions in collisions of heavy nuclei at RHIC and the LHC has become an important direction of the research program of these facilities in recent years. In particular, the production of vector mesons in ultra-peripheral collisions (UPC) has been intensively studied. Owing to the intense photon fluxes, the two nuclei participating in such processes undergo electromagnetic dissociation producing neutrons at beam rapidities. Here, we introduce the $\mathbf{n^{O}_{O}n}$ (pronounced noon) Monte Carlo program, which generates

events containing such neutrons. $\mathbf{n^{O}_{O}n}$ is a ROOT based program that can be interfaced with existing generators of vector meson production in UPC or with theoretical calculations of such photonuclear processes. $\mathbf{n^{O}_{O}n}$ can also be easily integrated with the simulation programs of the experiments at RHIC and the LHC.

4 Session 4

4.1 Recent results from b-BK

Marek Matas

Collinearly improved BK equation has been shown to suppress large non-perturbative contributions that were spoiling its predictions.

Our group was involved in this line of research and has published several papers that address the possible uses of the b-BK equation. I have discussed here the content and context of our recent papers that were focusing mostly on using the b-BK equation for the description of nuclear targets for the purpose of the planned electron-ion collider.

These works include predictions for the production of vector mesons, onset of saturation effects and properties of the Glauber-Gribov model.

4.2 Balitsky-Kovchegov equation at next-to-leading order

Dagmar Bendová

This contribution summarizes the theoretical development of the leading order Balitsky-Kovchegov equation towards the next-to-leading order precision and the current status of its numerical solutions. Balitsky-Kovchegov (BK) equation is one of the evolution equations of quantum chromodynamics (QCD) which describe the evolution of the partonic structure of hadrons. It is a non-linear integro-differential equation which describes dressing of a color dipole with decreasing Bjorken-x, which corresponds to increasing energy of the system. The equation therefore tells us the change of the dipole scattering amplitude with the increasing energy. This serves as an input into phenomenological applications to various QCD processes, e.g. predictions for deep inelastic scattering (DIS) or vector meson (VM) production. These processes can be described within the so called color dipole picture. In this approach, one of the interaction particles ? electron in case of DIS, or proton/nucleus in case of VM production in ultraperipheral collisions ? emits a virtual photon. This photon can be seen as fluctuating into the $q\bar{q}$ pair which can interact strongly with the target particle ? proton or a nucleus ? via exchange of gluons. Since the dipole and the target hadron are connected by a boost of the system, the BK equation describes both the evolution of the color dipole structure and the gluonic structure of the hadron. At leading order (LO), the equation describes the situation where one of the dipole constituents emits a gluon. In an appropriate limit, this gluon can be seen as a new $q\bar{q}$ pair. Therefore, the original dipole splits into two new

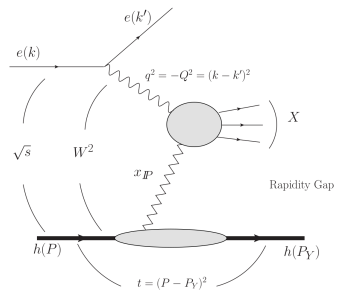
daughter dipoles, which can interact with the target hadron. Since the equation is non-linear, it also describes a possibility of recombination of the new dipoles back into the original dipole. The LO BK equation has been successfully used in description of above mentioned processes. The equation has also been solved with an explicit impact-parameter dependence. With the advance in theoretical description of QCD processes to higher orders of the perturbation theory, and the need of more precise description of experimental data and subsequent predictions for new measurements, comes also the need to solve the BK equation beyond leading-order. The full next-to-leading order (NLO) BK equation was proposed by Balitsky and Chirilli in Phys.Rev., D77 (2018) 014019. The subsequent works (Iancu et al.) have incorporated some of the NLO corrections into the LO version of BK equation and successfully used this equation in fitting the DIS data from HERA. The full NLO BK equation has been solved numerically by Lappi and Mantysaari in Phys. Rev., D91 (2015) 074016, however some instabilities of the numerical results have been reported. Using an appropriate resummation, the authors managed to obtain a stable numerical solution in their following work. However the numerical solutions of the NLO BK equation and its use in phenomenological calculations are still open topics, which are of high interest within the QCD phenomenology.

4.3 Diffractive deep inelastic scattering

Jan Čepila

The motivation to study the diffractive deep inelastic scattering is the fact that it can be used to improve our understanding of the behavior of the gluon distribution inside a hadron. It is known that towards larger scale Q^2, the number of gluons rises linearly but their size gets smaller. Also, towards smaller Bjorken x, the number of gluons rises linearly without changing the size. When the dilute system gets to dense regime (CGC) by crossing saturation scale Q_s^2, linear evolution no longer holds. Non-linear regime is described by infinite hierarchy of coupled (JIMWLK) equations for correlators of Wilson lines. But in mean field approximation and large N_c limit, the first equation decouples to single non-linear integro-differential equation for 2-point correlator - scattering amplitude of a dipole off the CGC matter.

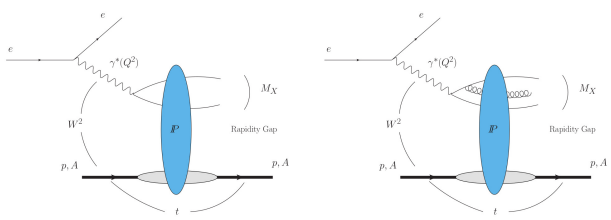
The diffractive deep inelastic scattering is a process where an electron scatters off the hadron leading to an electron + hadron + bunch of hadrons denoted as X,



where $W^2_{\gamma p}$ is the center-of-mass energy of the photon-hadron system, $Q^2 = -(k-k')^2$ is the scale of the incoming photon, $x_{\mathbb{P}} = \frac{Q^2+M_X^2}{W^2_{\gamma p}+Q^2}$ is a fractional longitudinal momentum loss of a hadron and $\beta = \frac{Q^2}{M_X^2+Q^2}$. Using those kinematic variables one can define Bjorken-x as $x_{Bj} = \beta x_{\mathbb{P}} = \frac{Q^2}{W^2_{\gamma p}+Q^2}$. The differential cross section for diffractive DIS can be expressed as

$$\frac{d\sigma^{eh\to eXh}}{d\beta dQ^2 dx_{\mathbb{P}}} = \frac{4\pi\alpha^2}{\beta Q^4}\left[1-y+\frac{y^2}{2}\right]\left(F_2^{D(3)}(x_{\mathbb{P}},\beta,Q^2) - \frac{y^2}{1+(1-y)^2}F_L^{D(3)}(x_{\mathbb{P}},\beta,Q^2)\right),$$

where y is the fractional energy loss of the electron in the hadron rest frame and $F_2^{D(3)}$ and $F_L^{D(3)}$ are diffractive structure functions. In the color dipole approach, we take a photon and expand it into the series of colorless parton states, that scatter elastically on the hadron



and if we restrict ourselves to two simplest states $q\bar{q}$ and $q\bar{q}g$, we can write

$$F_2^{D(3)} = F^D_{T,q\bar{q}} + F^D_{L,q\bar{q}} + F^D_{T,q\bar{q}q}(+F^D_{L,q\bar{q}q}),$$

where T, L denote the transverse and longitudinal degrees of freedom of the

photon and

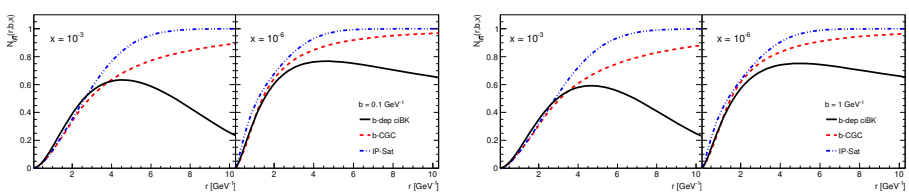
$$
\begin{aligned}
x_{\mathbb{P}} F^D_{T,q\bar{q}}(x_{\mathbb{P}},\beta,Q^2) &= \frac{N_c Q^4}{16\pi^3\beta}\sum_f e_f^2 \int_{z_0}^{1/2} dz z(1-z)\Big\{\epsilon^2[z^2+(1-z)^2]\Phi_1 + m_f^2\Phi_0\Big\} \\
x_{\mathbb{P}} F^D_{L,q\bar{q}}(x_{\mathbb{P}},\beta,Q^2) &= \frac{N_c Q^6}{4\pi^3\beta}\sum_f e_f^2 \int_{z_0}^{1/2} dz z^3(1-z)^3\Phi_0 \\
x_{\mathbb{P}} F^D_{T,q\bar{q}g}(x_{\mathbb{P}},\beta,Q^2) &= \frac{\alpha_s\beta}{8\pi^4}\sum_f e_f^2 \int d^2b_t \int_0^{Q^2} d\kappa^2 \int_\beta^1 dz \Bigg\{\kappa^4 \ln\frac{Q^2}{\kappa^2}\left[\left(1-\frac{\beta}{z}\right)^2 + \left(\frac{\beta}{z}\right)^2\right] \\
&\quad .\left[\int_0^\infty dr r \frac{d\sigma_g}{d^2b_t} K_2(\sqrt{z}\kappa r) J_2(\sqrt{1-z}\kappa r)\right]^2\Bigg\}
\end{aligned}
$$

$$
\epsilon^2 = z(1-z)Q^2 + m_f^2 \qquad z_0 = \frac{1}{2}\left(1-\sqrt{1-\frac{4m_f^2}{M_X^2}}\right) \qquad k^2 = z(1-z)M_X^2 - m_f^2
$$

$$
\Phi_{0,1} = \int d^2b_t \left[\int_0^\infty dr r K_{0,1}(\epsilon r) J_{0,1}(kr) \frac{d\sigma}{d^2b_t}(b_t, r, x_{\mathbb{P}})\right]^2
$$

$$
\frac{d\sigma_g}{d^2b_t} = 2\Big[1-\Big(1-\frac{1}{2}\frac{d\sigma}{d^2b_t}\Big)^2\Big]
$$

For the differential dipole cross section on proton $\frac{d\sigma_{q\bar{q}}}{d^2b_t} = 2N^p(r,b_t,Y)$ we have used three models - IPSat model,b-CGC model and impact parameter dependent solution of collinearly improved BK equation (bdepBK).



For the extension of the dipole scattering to nuclei we adopted several approaches. We have coupled IPSat, b-CGC and bdepBK model into the Glauber-Gribov approach

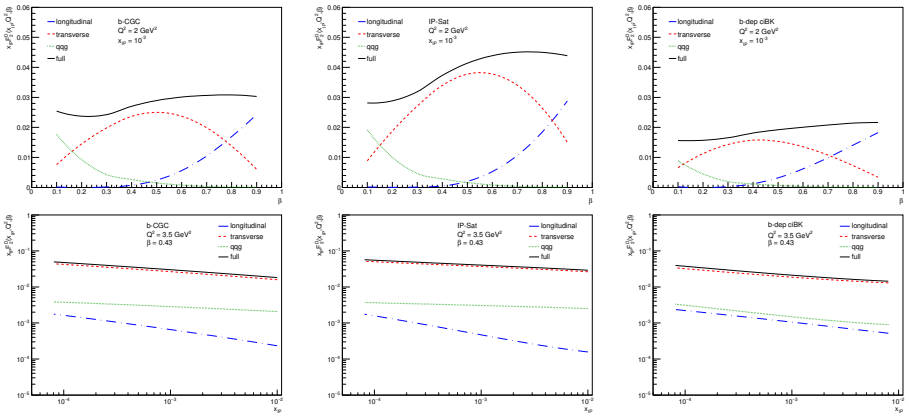
$$
N^A(r,b_t,Y) = 2\left(1-e^{-\frac{1}{2}\sigma_{q\bar{q}}(r,Y)T_A(b_t)}\right) \qquad \sigma_{q\bar{q}}(r,Y) = 2\int d^2b_p N^p(r,b_p,Y)
$$

and, finally, we have evolved the impact parameter BK equation using nuclear initial conditions (bdepBK-A)

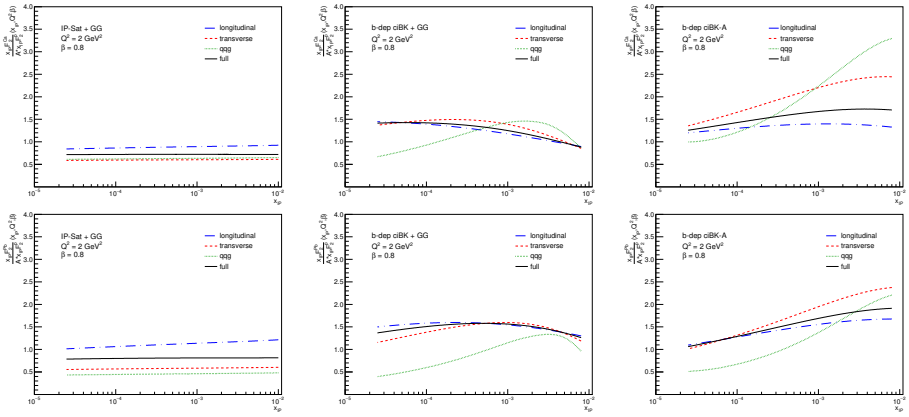
$$
N^A(r,b_t,Y=0) = \left(1-e^{-\frac{1}{2}\sigma_{q\bar{q}}(r,Y)T_A(b_t)}\right) \qquad \sigma_{q\bar{q}}(r,Y) = \frac{r^2 Q_{sA}^2(Y)}{4},
$$

where T_A is the nuclear profile function from Wood-Saxon distribution.

Results of our calculation for proton target show rather strong sensitivity to the chosen dipole model in the dependence of diffractive structure function on β, while the dependence on $x_{\mathbb{P}}$ shows similar behavior for all models.



Results for nuclear targets show strong model dependence for the dependence of nuclear modification factor on $x_{\mathbb{P}}$, where for IPSat model the factor is constant, for bdepBK in Glauber model the factor rises towards low $x_{\mathbb{P}}$ and for bdepBK-A model the factor drops.



Precise measurements at electron-nucleus colliders will allow to discriminate between proposed models and, consequently, will allow to find out which model for gluon distribution evolution hidden behind those models is preferred by data.

5 Session 5

5.1 Paper: Collinearly improved kernel suppresses Coulomb tails in the impact-parameter dependent Balitsky-Kovchegov evolution

Matěj Vaculčiak

The collinearly improved kernel was shown to provide a natural way to fix the problem of Coulomb tails. These were previously emerging in the solution of the impact-parameter-dependent Balitsky-Kovchegov equation and had to be dealt with in a rather artificial way.

Furthermore, the newly obtained dipole scattering amplitude was used to make theoretical predictions of the proton structure functions and the differential cross section of the exclusive J/ψ photoproduction, both exhibiting a great agreement with experimental data.

A prediction of the transverse momentum dependent Weizscker-Williams gluon distributions was also presented, providing a potential point of interest of future electron-ion collider facilities.

Besides the mere content of the paper, the background physics of the Balitsky-Kovchegov equation was also discussed. The focus was put on the deep inelastic electron-proton scattering, the content of parton model, and related quantities such as structure functions.

5.2 Lepton Pair Production Through Two Photon Process in Heavy Ion Collisions

Roman Lavička

This presentation was covering a recent paper about Lepton Pair Production Through Two Photon Process in Heavy Ion Collisions (arXiv:2003.02947v2). This paper focused on investigation of Electro-Magnetic production of lepton pairs with low p_{T}, especially authors estimate the initial photons' transverse momentum distribution and discuss a possible origin of p_{T}-broadening effect in quark-gluon plasma. The first was shown in the talk in more detail.

The estimation of the initial photons' transverse momentum distribution is based on equivalent photon approximation (EPA) and done through average transverse momentum squared. This way, authors found an inter-dependence of the photon distribution between p_{T} and impact parameter b_{T}. The resulting inter-dependence is not in agreement with so-called QED approach. Therefore authors introduced generalized EPA (GEPA), which calculates photon Wigner distribution. This was combined into two-photon process and transverse momentum distribution of the process was derived. The result was with in agreement with QED approach and the model was able to describe data measured by ATLAS well.

5.3 Probing Extreme Electromagnetic Fields with the Breit-Wheeler Process

David Horák

A Breit-Wheeler process is a type of interaction where electron-positron pair is created from the collision of two real photons. It is a fundamental process in astrophysics. STAR experiment at RHIC studied this process in ultra-peripheral Au–Au collisions (UPC) at $\sqrt{s_{\mathrm{NN}}} = 200\,\mathrm{GeV}$, where a two photon interaction may occur due to the contraction of electromagnetic field of Au ions. The electron-positron pairs were identified using a Time-Projection Chamber and extensive work on particle identification, to ensure a 99 % clean sample, was done. The proof of the Breit-Wheeler process is given by studying the invariant mass, transverse momentum and polar angle distributions. All mentioned distributions showed expected smooth curves that are compared to theoretical predictions. Both data and theory are in excellent agreement around 1 sigma. The UPC data are then compared to hadronic heavy-ion data. The distributions reveal a different shape and thus the data are sensitive to the initial collision geometry. The most significant result of the paper is the measured azimuthal angle modulation that is expected from collision of two linearly polarized photons in both UPC and hadronic data. The paper showed a possible method to study the Breit-Wheeler process and no deviation from theoretical prediction was found.

6 Session 6

6.1 Overview of UPC

Tomáš Herman

The proton structure in DIS described with parton distribution functions shows a steep increase in the number of soft gluons at low Bjorken x. The expected nonlinear regime of QCD where gluon recombination balances gluon splitting is referred to as saturation regime. When exploring the nuclear structure, the experimental results show that the nucleus structure function is not a sum of the nucleon structure functions. This effect is called nuclear shadowing and it is expected that saturation is one of the reasons for it. Furthermore, it is expected that saturation sets in at higher x in nuclei with regard to nucleons.

The abovementioned phenomena can be studied in vector meson photoproduction. To observe photoproduction processes the hadronic interactions have to be suppressed. This can be achieved in ultra-peripheral collision where the impact parameter is larger than the sum of the radii of the colliding nuclei and at least one photon is exchanged in the interaction. The lead ions at the LHC are a very intensive source of high energy photons allowing to study gluon distribution functions at low Bjorken x.

The ALICE detector is capable of measuring photoproduction in central and forward rapidity regions using the central barrel detectors and the forward

muon spectrometer. For background suppression and triggering the V0 and AD detectors are used.

In the data analysis the invariant mass and pt spectra are used to extract the number of vector meson candidates and determine the coherent or incoherent contribution which is used to compute the final cross section.

6.2 Measurement of the t-dependence of coherent photoproduction of J/ψ at midrapidity in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

Roman Lavička

Ultra-peripheral collisions of heavy ions were studied with ALICE at the LHC at energy of $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. Data with luminosity of 232.8 $\mu\mathrm{b}^{-1}$ were collected in autumn 2018. These were used to calculate cross sections of coherent photoproduction of J/ψ at midrapidity in different p_{T}^2 intervals. The J/ψ meson was chosen for its high mass (allowing perturbative QCD calculations), clear experimental signal and high cross section. The t-dependence is sensitive to the gluon distribution of the target in the impact-parameter plane. This measurement in inclusive to similar rapidity-dependent analysis.

The signal yield was taken from single Crystall-Ball extended likelihood fit of unbinned data. Then, it was corrected on contamination from similar incoherent process and feed-down from ψ' meson. The first was estimated from extended likelihood fit of unbinned p_{T}-spectrum data with a complex model. The second was estimated from ratio of ψ' to J/ψ yields. The migration of data amongst different p_{T}^2 bins was solved with unfolding based on Bayes' theorem. The cross section is also corrected on detector reconstruction efficiency, event-tagging algorithm inefficiency and electro-magnetic dissociation effect.

6.3 Towards the incoherent J/ψ photoproduction cross section

David Grund

The incoherent photoproduction of vector mesons, such as J/ψ, in ultra-peripheral collisions (UPCs) of heavy ions is a process that is sensitive to the transverse structure of hadronic projectiles. In UPCs, the participants are collided at the impact parameter which is larger than the sum of their radii. Owing to the short range of the strong nuclear force, such processes are induced by a virtual photon that is emitted by one of the nuclei and that interacts with the latter. In the incoherent case, the photon interacts with a just single nucleon in the target nucleus and a vector meson with the transverse momentum of several hundreds MeV can be produced. Analysing the incoherent photoproduction with ALICE at the LHC, one can study gluonic fluctuations in lead nuclei.

In the talk, the concept of an energy-dependent hot-spot model that describes the transverse structure of nucleons in UPCs in terms of Gaussian hot spots, number of which grows with the increasing energy of the collision, was

introduced. The previous measurement of the incoherent J/ψ production with ALICE based on the data from the Run 1 (2011) was summarized.

The main purpose of the talk was to present the results of the first steps of my analysis of the midrapidity incoherent J/ψ photoproduction using the data from the Run 2 (2018), which were collected at the larger centre-of-mass energy of 5.02 TeV. The selections applied to extract the incoherent events were described, as well as the perfomed calculation of the integrated luminosity of the utilized UPC central barrel trigger. The invariant mass distributions of both the coherent and incoherent-enriched samples were presented. A considerable increase in the number of incoherent events was found with respect to the previous analysis by ALICE. This means that the statistical errors can be substantially reduced and more systematic studies to reduce the systematic uncertainty could be performed.

6.4 Efficiency loss in PbPb due to EMD

Vendulka Flová

Measured cross section of J/ψphotoproduction consists of two contributions. One contribution corresponds to a high-energetic photon interacting with a nucleus and the second term corresponds to a low-energetic photon probing low-x gluons. An interaction of high-energetic photon is sensitive to lower-x gluons than the low-energetic photon. However, we are not able to disentangle these two contributions because we do not know which nucleus was the emitter of the photon and which one was the absorber in the interaction.

The photoproduction of J/ψvector meson can be accompanied by independent electromagnetic dissociation. Neutrons and charged particles can be produced in electromagnetic dissociation. Measuring the cross section in different neutron classes gives us an opportunity to separate the low and high-energetic photon contributions and investigate the gluon densities at values down to $x \sim 10^{-5}$.

In electromagnetic dissociation (EMD) one or more neutrons are emitted from 70% but also, less frequently, charged particles can be produced. In ALICE detector, muons (decay products of J/ψin forward rapidity) are measured in Muon Spectrometer, neutrons are detected in both-sided Zero Degree Calorimeters and charged particles produced in forward rapidities can be detected by V0 and AD detectors, located on both sides of the interaction point.

In a paper measuring J/ψcross section published by ALICE last year, the main trigger called CMUP11-B-NOPF-MUFAST was used. This trigger has vetoes on V0A, ADA and ADC implemented. In the analysis, the possible EMD has not been taken into account and no control trigger was active that would allow us the correction for event with additional EMD collision. The new problem was identified and one has to be creative and use different data samples to determine the correction.

In my talk I presented how the efficiency loss due to EMD in different neutron classes was determined. I described what data sample was used for the analysis. I also talked about the procedure of correction on pile-up events and

correction on vetoed events missing in the sample. The obtained corrections due to the charged particle production in EMD are significant in two neutron classes, therefore these processes have to be taken into account in measuring the cross section of J/ψphotoproduction in Pb–PbUPCs.

7 Session 7

7.1 Recent Results on Coherent ρ^0 Vector Meson Photoproduction

David Horák

The photoproduction of ρ^0 in UPC collisions is an excellent tool to study the black-disk limit regime of QCD because of its large cross section. ALICE reports the first measurements of coherent rho photoproduction accompanied by electromagnetic dissociation (EMD) with data taken at $\sqrt{s_{\mathrm{NN}}} = 5.02\,\mathrm{TeV}$. The rapidity-dependent cross section of coherent ρ^0 photoproduction is measured and it is compared to theoretical models. In addition, a resonance-like structure around $1.7\,\mathrm{GeV}/c^2$ is observed and compatible with STAR and HERA results.

During 2017, ALICE recorded the data from Xe–Xe collisions at $\sqrt{s_{\mathrm{NN}}} = 5.44\,\mathrm{TeV}$. The rare UPC trigger provide a sufficient amount of data to study the ρ^0 photoproduction cross section at midrapidity. The theoretical predictions slightly overestimate the data. The fraction of events accompanied by electromagnetic dissociation of either one or both colliding nuclei is presented and compared with the predictions of the NOON model and they are in a good agreement. These Xe–Xe results will be published in the near future.

The dependence on A of the cross section for the coherent ρ^0 photoproduction from results above is fitted using a power-law function. The power-law exponent is smaller that what is expected from a purely coherent process showing that the QCD effects are important.

7.2 Anisotropic flow measurements in high energy hadron collisions

Daniel Mihatsch

Ultrarelativistic heavy-ion collisions are studied at the ALICE experiment. In these collisions the quark-gluon plasma (QGP), state of matter in which quarks and gluons are deconfined, is created. The properties of created medium can be studied by anisotropic flow measurements.

The collisions are usually not central, so the shape of created medium is not sphere, but rather something like almond. Consequently the expansion is not uniform, but there are bigger pressure gradients in some directions than in others. In the result it causes anisotropy in the particle distribution (collective behavior). The azimuthal distribution of particles can be expanded in

Fourier series and anisotropy of produced particles is then quantified by relevant coefficients v_n.

Data from measurements shows that the Fourier coefficient of second order, which is called elliptic flow, has the largest amplitude and shows the strongest dependence on centrality. It is consistent with the idea of elliptic shape of interaction area in peripheral collisions. The amplitude of all coefficients is increasing with the increasing energy of collision. From comparison of data from experiment with the hydrodynamic model, the viscosity of the QGP can be determined. The exact value still depends on unknown parameters, but it is already clear, that the QGP is probably the most ideal fluid observed.

In small collision systems (p+p, p+A) no collective behavior was expected for years and they were used just as control measurements. But in 2010 the CMS collaboration analyzed data from high multiplicity proton-proton collisions and surprisingly they found signs of collectivity in two-particle correlation measurement. It becomes a motivation for searching of another collective behavior in small systems. Afterwards the negative value of four-particle cumulant $c_2\{4\}$ as evidence of collective behavior was measured and two other collective phenomena (mass-ordering and splitting of trend for mesons and baryons) were observed in small systems.

The latest part of my work is analysis of proton-proton collisions from Pythia. My motivation and goal was to try methods used for analysis of data from small system collisions, especially the subevent method used for suppression of non-flow correlations (jets and decays). In result I measured v_n dependence on multiplicity, where significant dependence of elliptic flow on multiplicity can be observed. I also verified, that the subevent method effectively suppresses non-flow correlations in measurements of elliptic flow v_n and cumulant $c_2\{4\}$.

7.3 Flow: selected topics

Katarína Křížková Gajdošová

Measurements of anisotropic flow in small collision systems with high multiplicities revealed signs usually interpreted as the manifestation of presence of the Quark-Gluon Plasma (QGP) in heavy-ion collisions. Proper treatment of non-flow contamination is of great importance, since small systems are largely affected by it. One of the methods to suppress this contamination is called the subevent method. It consists of splitting the detector acceptance in pseudorapidity into two or more subevents, ideally further separated by a pseudorapidity gap. A general rule applies, that the larger the $|\Delta\eta|$ gap there is, the larger the non-flow suppression we have. However, there is an effect, which may become visible at large $|\Delta\eta|$ gaps.

This is related to the decorrelations of the flow vector V_n, where either its magnitude, the v_n, or its phase, the flow angle Ψ_n, fluctuate in pseudorapidity. This would influence the standard flow measurements, with a larger effect when a large $|\Delta\eta|$ gap is present. Measurements using the r_n ratio were done by CMS, ATLAS and ALICE in heavy-ion collisions in order to investigate these

flow vector decorrelations. These fluctuations are linked to the fluctuations of the initial state. Therefore, it is of great interest to perform such studies also in small systems, since the flow measurements there predominantly origin from fluctuations. In addition, the new MFT detector may greatly improve these measurements in both heavy-ion and small collision systems.