Druhy miniworkshop difrakce a ultraperiferálních srážek

Anotace prezentovaných příspěvků

Session I:

- **<u>Flow, correlations and all that</u>**
  Katarína Křížková Gajdošová

  Signs of collective behaviour, usually interpreted as the manifestation of presence of the Quark-Gluon Plasma (QGP) in heavy-ion collisions, were also revealed in small collision systems. These collision systems were not expected to create such a state of matter, thus it is of great interest to investigate the reason behind these observations. An experimental overview of the latest results in this topic was presented.

  Correlations among final state particles with respect to a common symmetry plane, spanning long range in pseudorapidity, are one of the signs of the collective expansion of the Quark-Gluon Plasma created in collisions of heavy ions. Numerous measurements performed in small collision systems, such as pp or p-Pb collisions, indicate presence of collectivity. An example are measurements of multi-particle correlations of charged particles, or the observation of a baryon-meson grouping in measurements of flow coefficients of identified particles.

  Whether the origin of this collective behaviour is from initial state, or from final state (QGP-like), is further investigated by comparison of experimental data to model calculations. Models including a final state are able to quantitatively describe measurements of flow coefficients calculated from two-particle correlations. However, measurements of multi-particle correlations are not yet reproduced even on a qualitative level.

  Understanding of the initial stages of a collision seems to be important for a proper modelling of small collision systems. One of the crucial improvements was the addition of a proton substructure. Without this assumption, the models underestimated the measured data. Thus, a measurement sensitive to initial conditions of a collision is necessary to further constrain theoretical calculations. One of such measurements are symmetric cumulants, which have been measured in small collision systems, where they revealed similar patterns as seen in heavy-ion collisions.

  Measurements of multi-particle correlations in more exotic collision systems, such as electron-positron or photo-nuclear collisions, can bring additional information to the question of the origin of collectivity observed in pp and p-Pb collisions.

  The interpretation of such observations is still not resolved. While the number of measurements in various collision systems at the LHC rises, the comparison to model calculations, which is essential for deeper understanding of the observed phenomena, lags behind.

- **UPC**
  Jesús Guillermo Contreras

  Ultra-peripheral collisions refer to interactions at hadron collider mediated by at least one photon. This type of process allow us to study in detail the evolution of the perturbative QCD structure of hadrons.

  In this lecture the UPC which produced a vector meson are described in detail, including the kinematics, the latest measurements and new ideas to relate better the experimental results with the theoretical formalism.

- **Wave functions**
  Jan Čepila

  The deep inelastic scattering of very energetic electron on a proton target can be described using the so called structure function of the proton $F_2(x,Q^2)$, where x is the Bjorken-x and Q^2 is a square of the four-momentum transferred in the scattering. The structure function can be written in terms of the transversal and longitudinal cross sections $\sigma_{T,L}^{\gamma^\ast p}(x,Q^2)$ of the scattering of transversally and longitudinally polarized virtual photon emitted by electron with target proton. They can be calculated in the light-cone color dipole model in a frame, where proton is at rest using the cross section of the strong interaction of a quark-antiquark dipole with the target proton $\sigma_{q\bar q}(x,r,b)$ and a square of the wave function (probability amplitude) of a situation where photon splits into a quark-antiquark pair (or better probability amplitude that the $q\bar q$ Fock state of the infinite Fock decomposition of a photon joins the interaction) $|\psi_{\gamma^\ast\rightarrow q\bar q}^{T,L}(\vec r,z,Q^2)|^2$, where $ \vec r $ is the transverse dipole size, $ \vec b $ is the impact parameter of the dipole(transverse distance from the center of the proton to the center of mass of the dipole) and $ z $ is a part of photon momenta carried by one of the quarks from the dipole.

  The dipole cross section is model dependent and cannot be derived from the first principles. However, the wave function can be derived from QED as a vertex $\gamma\rightarrow q\bar q$ in a light-cone frame. The wave function can be either defined in a mixed representation ($r-z$) and one has to formulate the vertex operator directly in the mixed representation, or it formulate the vertex in momentum representation (conventional QED) and then use the Fourier transformation of the wave function from momentum representation to mixed representation. Using the former approach, the wave function is defined using spinors of a quark and antiquark χ_j and χ_i and operators $\mathcal{\hat O^{T,L}}$, that are composed of a vector of Pauli matrices $\vec\sigma$, a polarization vector of incoming photon $\vec e$ a unit vector in the direction of photon propagation $\vec n$, a twodimensional vector of derivatives w.r.t. r - $\vec\nabla_r$ and modified Bessel function K_0.

It was assumed that the frame of reference is such that the photon comes in the positive direction of the z axis and so the vector $\vec n$ points in the direction of $\vec e_z$ and the vector $\vec r$ is perpendicular to the z axis. Also, for longitudinally polarized photons the polarization vector goes along the photon propagation while for transversally polarized photons the polarization vector goes perpendicular to the photon propagation.

In this frame the derivation of the square of the wave function was shown by applying the operators to the spinors and summing over all possible helicity states and over all possible quark flavors. The correct formula was resembled under one condition that the angle between $\vec n_r$ and $\vec e_x$ is equal to zero. Since there is a However, we have a degree of freedom to choose the orientation of the dipole w.r.t the plane $\vec e_x \times \vec e_z$.

- **BK equation**

  Marek Matas

  The Balitsky-Kovchegov evolution equation is one of the key tools for understanding perturbative quantum chromodynamics on the hadronic level. It can be used for the description of various experimental data such as structure function obtained by the deep inelastic scattering experiments.

  During my talk at Decin, I have explained how it can be derived in the Mueller approach to dipole model and how the limit of high number of colors simplifies the derivation by the treatment of the emitted gluon as quark-antiquark pair which then splits the mother dipole into two.

  I have also shown how the non-linear properties of this equation incorporate gluon recombination effects and give rise to saturation, which is intensely sought in the current experimental data.

  In the latter discussion we have also addressed how di-jet events can be used for such searches and how different kernels effect suppression of some parts of the phase space that the BK equation solves.

Session II:

- **Overview of MFT**

  Jesús Guillermo Contreras

  The ALICE collaboration is composed of almost 2000 scientists from all over the world. Their goal is to design, build and maintain in operation a detector system installed in the collision point 2 of the Large Hadron Collider (LHC).

  The operation of the LHC is divided in periods of data taking, called Runs and lasting 3 to 4 years, and periods of upgrading of the infrastructure called Long Shutdown (LS). Right now, we are in the LS2 in preparation for Run 3 at the

LHC. ALICE is preparing the upgrade of the detector, which includes among other a new detector system: the Muon Forward Tracker or MFT.

The basic element of the MFT is a sensor with almost half a million silicon pixels that can be readout and form the signal of the detector. These sensors are organised in ladders and the ladders are in each of the two faces of half disks. In total there are almost 1000 sensors, making this detector a 500 M pixel camera.

This talk describes the detector project, the current state of the system and the contribution of our group to this enterprise.

- **<u>Overview of QC</u>**
  Katarína Křížková Gajdošová

  Quality Control (QC)

  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. This is motivated by large anticipated interaction rates during the next LHC running, which resumes in 2021. In order to cope with the large induced pile-up, and at the same time not loosing large fraction of data, many of the ALICE detectors will read-out the data in a continuous mode, instead of selecting only a fraction of events.

  To cope with the continuous data read-out, ALICE software will be built from scratch under the name O^2, which stands for ``Online and Offline''. It will be able to read the data and perform partial data reconstruction synchronously, and at the same time it will serve for offline (asynchronous) final data reconstruction, and for user analyses.

  Due to this new software framework, the monitoring of the data quality will also modify its working principle. During the data taking periods before the LS2, ALICE had two levels of monitoring of data: Data Quality Monitoring (DQM) and Quality Assurance (QA). The first one served as an online tool for shifters sitting in the ALICE Control Room to spot any immediate problems in the quality of data that were being taken. The QA was done offline in form of more complex checks, such as trending plots monitoring the dependence on time.

  The new Quality Control (QC) introduced in the next LHC run will encompass both online and offline data monitoring. Several different QC tasks can be running in one framework. Each task accesses different format of data, depending on which stage of the data flow it will be performed: these can range from raw data to final reconstructed data in a reduced form of the so-called AODs.

A general principle of a QC task starts with a data sampling. In most cases, only few \% of the whole data sample is enough to validate the quality of data. Thus, the first stage is to sample the data according to the needs of each detector QC. Then, the main body of the QC task fills the input data to monitoring objects, usually histograms. The information stored in the histograms will be then evaluated by a Checker, and together with its decision published to a web interface, accesible by shifters or users.

Each of the ALICE detectors is responsible for developing its QC task. A skeleton task is provided to maintain the general form, but the monitoring histograms are specific to each detector system. The whole software should be ready for use before the start of the next LHC run..

- **Latest news on MFT from CERN**
  Diana Krupová

  This talk reported on the latest news on MFT (Muon Forward Tracker) from CERN. MFT is a part of ALICE ongoing upgrade during the Long Shutdown 2. The LHC will start collecting data again in 2021, so until then, all detectors need to get upgraded and ready to be used for various purposes. MFT is a silicon tracking detector, it will allow ALICE to achieve better precision in measurements of quark-gluon plasma properties. The MFT detector itself consists of two half-cones, each of which is built from half-disks consisting of ladders. In every ladder, a specific number of silicon ALPIDE chips is used. The silicon pixel sensors were developed for both ITS (Inner Tracking System) and MFT. The MFT upgrade project is currently in ladders assembly and testing phase.

  After having worked on ladders assembly and testing at CERN DSF (Department Silicon Facility), I presented MFT ladder assembly scenario, images of workspaces used in chip picking and ladder assembly, thoroughly described the process and also the current problems we are facing. The next part of my talk presented the methods used in ladder qualification tests - the main focus of my stay at CERN. I described all parts of testing, mainly the smoke test needed to safely perform tests which followed.

  The organization of workspace in grey room was shown together with the installation of a black box to cover the ladders while performing the tests to ensure no light hit the chips. Functional tests were described - consisting of FIFO scan, digital scan, threshold scan, noise occupancy and eye measurement, each measurement responsible for QA of different part of the ladder. Threshold distributions measured without back-bias and with back-bias voltage were compared. Finally, the recent status of qualification results was presented.

- **Overview of FDD**
  Jesús Guillermo Contreras

The ALICE collaboration is composed of almost 2000 scientists from all over the world. Their goal is to design, build and maintain in operation a detector system installed in the collision point 2 of the Large Hadron Collider (LHC).

The operation of the LHC is divided in periods of data taking, called Runs and lasting 3 to 4 years, and periods of upgrading of the infrastructure called Long Shutdown (LS). Right now, we are in the LS2 in preparation for Run 3 at the LHC. ALICE is preparing the upgrade of the detector, which includes among other a new detector system: the Forward Diffraction Detector or FDD.

The FDD consists of two arrays, each placed about 20 m away, and at both sides, of the interaction point along the direction of the incoming colliding beams. Each array has four sectors and each sector is composed of two modules placed in parallel. Each module is composed of a plastic scintillator read out by wavelength shifters coupled to clear fibres leading the produced light to a PMT. From then on, the signal uses the same electronics as FIT, adapted to the special properties of the FDD.

The talk gives an overview of this detector and of the involvement of our group in its design, construction and operation.

- **<u>FDD software</u>**
  Michal Broz

  The software for FDD consists of code for hits creation, digitization and reconstruction. Geometry of the detector implemented so far consists of final active volume: scintillator blocks and wave length shifting bars.

  Mechanical support is to be ported/adjusted from previous code. FDD store one hit per charged track crossing the scintillator. For every hit we integrate number of photons created at each step using energy deposition and light output of the scintillator. Digitizer simulates the route Photons - Photo Electrons - PMT amplification - Signal pulse. Digitizer workflow is as following: Total charge per Hit from PMT is computed using number of photo electrons and PMT gain. Total charge is distributed over pulse per photo electron using time and amplitude response of the PMT. For every photo electron the mean time is spread according to signal shape: function simulates the time of arrival of the photons at the photocathode, gain variation is modeled using photo electron spectrum, time distribution of the signal per photo electron is parameterized by PMT transit time.

  Hit data structure contains: Base hit info + Number of photons. Digit contains: Channel data structure with ADC charge, Time and various bits (bool) as sent by FEE, IR, Event time. Reconstruction from Digits has been implemented. We copy the channel data structure from Digits as it is and compute the mean time per side (charge weighted average).

Session III: Basic literature I

- **Overview of MFT database**
  Roman Lavička

  LHC is currently in a period called Long Shutdown 2, which is a 2 years long break serving to improve accelerator facility with a final goal to significantly increase luminosity of particle beams. The ALICE experiment is taking advantage of this period to also improve its detector systems and include new detectors. One of the new detectors is so-called Muon Forward Tracker (MFT).

  Currently, parts of the detector are being constructed. This detector consists of several disks, which are composed of many ladder of four different types. Each ladder is created of one flexible printing circuit and several chips, depending on type of ladder. This together gives tens of thousands pieces, which has to be manufactured, modified and tested.

  The MFT production database serves to monitor and to store information on each step of the production of each detector piece. This talk describes definition of all components and all activities performed during production, in the database. The chain of activities with all prerequisites is presented. The database can be approached in two way – using web browser or using API remote control. Meanwhile the web browser is used to define all components and activities, the presented API control machinery serves to fill the database with real data. A practical show of the remote control of the database was a part of the presentation.

- **Luminosity tools**
  Roman Lavička

  Integrated luminosity is a feature defining in more general way an amount of data we collected during some period. This is a core variable in all cross section calculations. More luminosity we have, more statistics we have collected and hence better precision of cross section measurement we achieve. The ALICE experiment run coordination have to deal with a limited amount of days of stable beams, when they can collect data. The scientific community wants to achieve multiple goals with multiple processes during this limited time period. However, these processes are competitive in a way of data taking – one has to decide, what portion of data bandwidth would be used for which process. Calculating the integrated luminosity for each process each day and comparing them help to the run coordination to plan the whole data collection period with maximum efficiency.

  This talk is about a tool which provided this information to run coordination between years 2015 and 2018. Additional usage of the calculated luminosity in standard analyses is also discussed. In addition, definition of ALICE trigger system and description of the luminosity calculation is also provided.

- **ZDC migrations**
  David Horák

  The coherent vector meson photoproduction is at high-energies accompanied by forward neutrons. The probability of the emission is predicted by models. Measuring the cross section for different forward neutron samples can provide an energy dependent of the gamma-target cross section. At ALICE these can be precisely measured using separation in zero-degree calorimeters (ZDC). However, there are several issues in such analysis. Firstly, ZDC acceptance and efficiency has to be known. It can be estimated by measuring electromagnetic dissociation (EMD) cross section and comparing to models (e.g. RELDIS). Secondly, due to the large EMD cross section there is a big probability to have another UPC collision (so called pile-up) producing an EMD event. This will lead to misidentification of the ZDC class. We can compute a correction factor, if we know the probability to have an EMD on top of the studied process. At ALICE it can be studied using CTRUE events (special trigger that is fired at each bunch-crossing). Then we derived formulas that will correct this effect. Another solution we found is to study the pile-up dependence of the measured cross section which will provide the required correction factor. Lastly, the assumption that only neutrons are produced is not correct. For example, a nucleon in a nucleus may be excited to a Delta+ resonance and emit a pion when a resonance decays. This pion might be detected in the AD detectors, causing a veto and therefore reducing number of events in our ZDC samples. We studied this effect again using a CTRUE data.

- **Extraction of the photonuclear cross section**
  Tomáš Herman

  The cross section measured in ultra-peripheral nucleus-nucleus collisions (UPC) at forward rapidity consists of two contributions. Due to the ambiguity in the source emitting the photon there is a process involving a high energy photon which is probing a low Bjorken x gluon and a second process where a low energy photon probes a higher x gluon. At LHC energies it is possible to reach values of Bjorken x in the order of 10^{-5} for the gluonic distributions in the high energy photon contribution.

  This gluonic distribution is poorly known and therefore of great interest. To be able to separate the two contributions the UPC cross section has to be measured in the same rapidity range but in different impact parameter classes. This can be achieved by measuring the cross section in classes based on the number of forward neutrons emitted due to independent soft electromagnetic interactions during the collision.

  A method implemented in an enclosed c++ macro extracting the photon-nucleus cross section (and thus the information about the gluonic distribution) from the UPC cross section was presented together with instructions on how to use the macro. Also, a short test on the error propagation from the computation inputs to the results was presented stressing the importance of carefully managing the errors.

- **<u>A generator of forward neutrons for ultra-peripheral collisions: nOOn</u>**
  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 nOOn Monte Carlo program, which generates events containing such neutrons. nOOn 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. nOOn can also be easily integrated with the simulation programs of the experiments at RHIC and the LHC

Session IV:

- **<u>Goods-Walker approach</u>**
  Jesús Guillermo Contreras

  This talk presents the classic paper *Diffraction Dissociation of Beam Particles* written by M. L. Good and W. D. Walker and published in Phys.Rev. 120 (1960) 1857-1860.

  Before going to the paper itself a brief overview of the discovery of the dissociation of light is given. Then the paper itself is described. First, it is described how the authors make sure that the process they are interested in has enough energy at its disposal to proceed and then they discuss that it is not only possible from the energetic point of view, but also possible. This last issue is argued, more than demonstrated.

  After that, the authors develop the correct quantum mechanics treatment of such a process and present some observations regarding to its behaviour. In conclusion they state that such a process, the dissociation of hadrons, can occur and that the produced particles will appear in a narrow cone in the forward direction as expected by diffraction.

- **<u>Diffraction Scattering and the Parton Structure of Hadrons</u>**
  Marek Matas

  I have presented a summary of a paper that treats the diffraction of two hadrons as a scattering of soft partons (this group on purpose avoided coining the term gluons since the QCD property of such objects was uncertain at that time) with a potential barrier that represented the other hadron.

They have shown that the diffractive cross section is given mainly by the statistical fluctuations of its constituent soft partons and have dissected the cross section into the individual contributing fluctuations (in position, energy and number of partons).

They have also shown that such a simple model surprisingly well describes data and qualitatively explains the peripheral nature of diffractive scatterings. During my talk, I have explained the peripherality with a simple gedanken experiment in which a quantum harmonic oscillator traverses through a homogenous barrier that suppresses its wave function.

When the collision is peripheral, the wave function is distorted, and its shape gives rise to new eigen functions in the Fourier decomposition. That is why diffractive effects are dominated by the peripheral events rather than central collisions.

- **<u>Hot-spot models</u>**
  Dagmar Bendová

The talk “Fluctuations of the inner structure of the proton and the dissociative production of vector mesons was based on the two recent papers in the field of phenomenology of quantum chromodynamics. The first one was “Evidence of strong proton shape fluctuations from incoherent diffraction“ by H. Mantysaari and B. Schenke, published in Phys. Rev. Lett 117 (2016) 052301. The second paper was „Energy dependence of dissociative J/psi photoproduction as a signature of gluon saturation at the LHC” by J. Cepila, J. G. Contreras and J. D. Tapia Takaki, published in Phys. Lett. B 766 (2017) 186-191.

In the motivation section of the talk, an evolution of the partonic structure of the proton and a related phenomenon of the saturation of gluon densities at large energies (or equivalently low Bjorken-x) was introduced. Subsequent part introduced an approach to the calculation of cross sections for the production of vector mesons which is used in both papers, the exclusive cross section can be obtained as a square of the mean value of the scattering amplitude while the dissociative process is related to the variance over different configurations of the proton structure. The color dipole approach to the calculation of the scattering amplitude of the process was introduced. Within this amplitude, the information about the proton structure and the strong interaction is incorporated in the cross section of the interaction between the color dipole and the target proton.

At this point, each of the groups applies different approach to the dipole-proton cross section and include fluctuations of the proton structures in the impact parameter (transverse) plane. Mantysaari at al. use so called constituent quark model, with fluctuating gluon clouds located around three valence quark of the proton, and fluctuating saturation scale. Cepila et al. use so called energy-dependent hot-spot model, which sees proton as a set of regions of high gluon density randomly placed in the impact-parameter plane.

Both of these two approaches provide a good description of the |t|-distribution of the exclusive photoproduction of a J/psi meson. Mantysaari et al. compare models with small and large-scale fluctuations and conclude that sizable fluctuations are needed in order to correctly describe the dissociative process. Approach to the subnucleonic fluctuations by Cepila et al. also provides very good description of the |t|-distribution of the dissociative J/psi cross section. Moreover, they also obtain a prediction for the total dissociative cross section which show a maximum of the cross section, which could be a sign of the saturation of gluon densities in the proton in the impact-parameter plane and they suggest that this phenomenon could be measured at the LHC.

- **<u>Albacete's model</u>**
  Tomáš Herman

  First, a paper by Albacete and Soto-Ontoso called "Hot spots and the hollowness of proton-proton interactions at high energies" has been presented. The paper focuses on explaining the onset of the hollowness effect, i.e. the depletion of the inelasticity density for most central pp collisions, at LHC energies. The group computed a Glauber-like multiple scattering series of collisions between gluonic hot spots which are deemed to be the effective degrees of freedom to describe this process. The main difference to previous work is the inclusion of short range repulsive correlations between the hot spots. The model successfully describes the effect as the onset of the hollowness phenomenon at LHC energies is explained by the growth of the energy dependent size of the hot spots.

  The second presented paper called "Correlated wounded hot spots in proton-proton interactions" is by Albacete, Petersen and Soto-Ontoso. This paper mainly explores the effect of the model developed in the previous work on the geometry of the initial state of proton-proton collisions. Based on results from a Monte-Carlo generator, developed by the group, with a Glauber approach and fluctuations in the hot spot positions they compute that the inclusion of the short range repulsive correlations results in a decrease of the eccentricity and triangularity of the collisions in the minimum bias data sample. However, when considering only the ultra-central collisions they report a significant increase in both the eccentricity and the triangularity of the initial state geometry.

Session V:

- **<u>Hot spots and symmetric cumulants</u>**
  David Horák

  The talk is about „Symmetric cumulants as a probe of the proton substructure at LHC energies". The motivation for this study is the experimental fact that measured NSC(2,3) cumulant was found to be negative at very high multiplicities in both p+Pb and p+p collisions.

  The main goal of this work is to relate this effect to the initial geometry of the proton. For that a wounded hot spot model was used. The group used three different correlation scenarios – one without any correlation force, another also without but with fixed parameters to the last one with correlations. The main results is that only the case with correlation can explain the observed negative sign of the cumulant and it is given at the geometric level. Then the symmetric cumulant was studied for different conditions according to number of wounded hot spots and number of collisions. The number of collisions was observed to be reduced when including repulsive correlations.

The explanation of this effect is that enlarging the distance between the hot spots reduces the probability of having high number of collisions. The negative part of the cumulant has its origin at configurations with a large number of collisions. The parameter space scan was done for different hot spot radii. It was found that NSC(2,3) depends on a generic function of the radius of the hot spot and the repulsive core distance.

The model was also extended for other numbers of hot spots, namely two and four besides natural three. The negative sign was not observed in the case with only two hot spots. The conclusion is that at least three hot spots have to be present in the model to properly describe the measured symmetric cumulants.

- **<u>Hot spots and flow</u>**
  Vendulka Filová

  The authors of this publication present result for particle production at centre-of-mass energies of 5.02 TeV in proton-lead collisions at the LHC within a combination of IP-Glasma model and relativistic viscous hydrodynamics framework. The importance of subnucleonic fluctuations in proton is emphasized for the description of experimentally observed flow vn coefficients.

  It is demonstrated how the flow coefficients are sensitive to the shape of proton. In heavy ion collisions azimuthal anisotropic particle distributions are produced in strong final state interactions. These distributions are strongly correlated with the initial event geometry. Similar azimuthal anisotropies were observed in proton-heavy ion collisions.

  It was suggested that the origin of the anisotropies could be the hydrodynamic response of produced medium in small system to the initial shape of the interaction region.

  In the model presented in the paper, the initial state and early time evolution is described by the IP-Glasma model. The field energy-momentum tensor from the IP-Glasma model provides the initialization for the relativistic viscous hydrodynamic simulation, called MUSIC. The last part of the calculation was determination of spatial and momentum distributions and their implementation into the hadronic cascade UrQMD from which the results were obtained.

The hydrodynamic evolution of IP-Glasma initial state in small systems has been explored before with results showing an underestimation of experimentally measured flow coefficients. In the original IP-Glasma model a 'round proton' shape was assumed.

The authors included additional subnucleonic structure to all nucleons using three gluonic hot spots.

The improvement of the IP-Glasma model lead to increase of flow coefficients in p+Pb collisions by approximately a factor of 5. The multiplicity dependence of transverse momentum, flow coefficients v2 and v3 were nicely described within this framework, as well as the transverse momentum dependence of the charged hadrons and identified particle flow coefficients for higher multiplicities. Furthermore, this model overestimates measured HBT radii.

- **Correlations in UPC according to ATLAS**
  Roman Lavička

  The ATLAS collaboration has measured two-particle long-range azimuthal correlations in photo-nuclear collisions and released a conference note about it in June 2019. This talk was presenting their results and how they fit in understanding the hot topic of current flow physics – how to explain the collective flow measured in small systems. In large systems, such as collisions of heavy ions, we can explain this phenomenon with creation of quark gluon plasma, however it is not expected to have this state of matter in small system.

  The technical part of the released note was discussed in the second part of the presentation. Data selection, including a detailed definition of a special cut on photo-nuclear events, was discussed as well as the extraction of elliptic coefficient v_{2} out of data. The systematic uncertainties were also shown. The goal of this second part was to understand all strong and weak points of the ATLAS measurement and to discuss a possibility of such measurement at the ALICE experiment.