Miniworkshop difrakce a ultraperiferálních srážek

Anotace prezentovaných příspěvků

Session I: Techniques I

- **Fitting in ROOT: how to do it and how to access the information**
  Tomáš Herman

  The ROOT framework is the standard software in the high-energy community to perform complex analyses of the data gather in the large collaborations like those at the LHC. One of the most frequently used functionalities of these framework is the ability to perform fits of models to data to extract the value of the model parameters as well as their uncertainties and correlations.

  To this end, on top of the standard original functions of ROOT, there is an embedded framework called ROOFIT, which has a particular syntax and offers extra capabilities not available out of the box in the original ROOT classes.

  Simple macros are presented, which perform fits to invariant mass distributions of J/ψ accompanied by backgrounds as found in typical analysis of diffraction at the LHC. The different ingredients are presented, as well as the techniques to extract the information from the fits.

- **Generating general 3D Gaussian distributions**
  Jan Půček

  One dimensional Gaussian distributions are commonly used by physics students at the bachelor level, but it is not so frequent that they are faced with their 3-dimensional counterparts. Even less frequent that they use the general formulation, which includes correlations in the three dimensions.

  For this general case, it is not trivial to generate random numbers. In this presentation the implementation of such a generator in the class *RooMultiVarGaussian* of the ROOT framework will be reviewed. User cases related to covariance matrices of vertex finding and implementation of a simulation in a van der Meer scan are mentioned

- **Unfolding**
  Roman Lavička

  The coherent photonuclear production of J/ψ is very interesting for a number of reasons. In particular, the measurement of the dependence of the cross section on the transverse momentum of the vector meson important. But the experimental resolution is of the order of the full available transverse momentum range, so the commonly used bin-to-bin corrections of acceptance and efficiency do not work.

The standard solution is to apply the so-called unfolding correction. There are several different methods to performed unfolding and it is not clear a priori which one is best suited for a given experimental condition. The general formalism of unfolding is presented along with the application to the concrete case of coherent photonuclear production of J/ψ in Pb-Pb collision at the LHC.

- **The Simpson and the Runge-Kutta methods**
  Dagmar Bendová

  One of the most useful theoretical tools to explore the high-energy limit of perturbative QCD is the Balsitsky-Kovchegov equation. This equation has to be solved numerically. Two techniques needed in this case are the Simpson method to perform integrals and the Runge-Kutta method to solve differential equations.

  Both methods are described in detail. In particular, the Runge-Kutta method is presented for different orders. First order or Euler forward method, second order as implemented in Huen's method and fourth order, commonly known as the classical Runge-Kutta method.

- **Computing Fourier Transforms**
  Marek Matas

  The Fourier transform is one of the tools more commonly used in Physics. In the case of diffraction and ultra-peripheral collisions one application is to transform the dipole scattering amplitude from coordinate space, as represented by the size of the dipoles to momentum space, represented by their transverse momenta. This representation of the dipole scattering amplitude is the fundamental building block of the so-called transverse momentum distributions (TMD).

  The methods to obtain the Fourier transform in this case, and for polar symmetry, are presented and discussed in detail. Different options are introduced, and the problems associated to their implementation are explained.

Session II: Techniques II

- **Amplitude for vector-meson photo-production in the colour dipole model: main components**
  Guillermo Contreras

  This short presentation, serves as the introduction to this part of the sections. It presents the different ingredients needed to compute the amplitude for the photo-production of one vector meson off a hadronic target. In the colour dipole model, this process proceeds in four steps. A photon is emitted by a source, the photon splits into a colour dipole pair, this dipole interacts with the target and then it creates a vector meson.

  These steps correspond to the ingredients coming into the amplitude, which are the photon flux, the wave functions of the photon splitting into a dipole and of a dipole forming a vector meson and the fundamental dipole scattering amplitude for the interaction with the target.

- **The photon flux**
  Guillermo Contreras

  The electric field of an electrically charged particle accelerated to relativistic velocities looks like a two-dimensional field due to the Lorentz field. The energy content of this field can be transformed to frequency space and decompose into the contributions of different wave lengths. Each of these contributions looks like a plane wave. The field can then be interpreted as a flux of quasi-real photons being emitted by the source.

  The formulas for the steps just described are presented and discussed in detailed. To use these formulas in practical applications one needs to include a model for the charge distribution of the source and perform numerical integrations. For the case of the ultra-peripheral collisions the implementation of the constraint that the incoming particles do not collide hadronically is also described.

- **Wave functions**
  Jan Čepila

  After the scattering with the target, the dipole collapses into a vector meson. This process cannot be computed analytically, because its non-perturbative character, so there are different models to describe this process. These models are discussed in the presentation.

  The models are based on the solution of the Schrodinger equation for different realistic potentials of the bound state formed by the quarks forming the vector mesons. The formal description of the problem, as well as its solution for a variety of potentials is presented in this talk.

- **Dipole scattering amplitudes**
  Jan Čepila

  The interaction between the dipole and the hadronic target is described by the universal dipole scattering amplitude, which depends on the size and impact parameter of the dipole and on the energy of the interaction with the target.

  There are a multitude of prescriptions for this amplitude. The most commonly used ones are discussed here. They include the model proposed by Golec-Biernart and Wuesthoff model, which is based on the simplest possible parameterization between the colour-transparency and the saturation regimes when assuming independence on the impact parameter. Other models including a dependence on the impact parameter are presented.

- **Kinematics**
  David Horák

  The basic kinematic equations for the photoproduction of a vector meson off a hadronic target in ultra-peripheral collisions are derived from scratch. This process allows one to obtain the full kinematics using as input the energies of the incoming hadrons, as well as the scattering angle and the transverse momentum of the scattered vector meson.

  Expressions for the different energies – centre-of-mass energy in the system of the incoming hadrons, in the system of photon and the target – are computed. The energy of the photon in the laboratory system as well as the momentum transferred in the hadron vertex are also derived.

- **An analysis in ALICE: from data taking, to publication**
  Michal Broz

  All the steps to go from an analysis to a publication using data from ALICE are discussed. First, how to choose a good subject, how to discuss the advances in the different analysis groups, and where to find some examples to start with a new analysis. A simple example of the code is introduced and discussed. The role of preliminary results and its relation to conference talks is presented and the relevant rules in ALICE discussed. Finally, the steps to turn an analysis into a paper and how to push it through the collaboration is explained.

Session III: Basic literature I

- **A comment on parton distributions**
  Guillermo Contreras

  The path from a matrix element computed in quantum field theory to the concept of a parton distribution, specifically a collinear PDF is presented based on a diagram from Eur. Phys. J. A52 (2016) 149. The paths to reach generalized parton distributions, Wigner functions and transverse momentum distributions are presented.

- **DIS at HERA**
  Guillermo Contreras

  One of the main tasks of the H1 and Zeus Collaborations at the HERA accelerator in Hamburg was the mapping of the structure function of the proton using deeply inelastic scattering.

  The latest of these collaborations are reported on Eur. Phys. J. C75 (2015) no.12, 580. Here we give a brief overview of these results and their interpretation. The main highlights are (i) the large phase space covered by the measurements of the F2 structure function and the small experimental uncertainty, (ii) the extraction of the PDFs for each parton species and the experimental proof that at small x the structure of the proton is dominated by gluons, and (iii) the measurement of the neutral current cross section as a function of the virtuality of the exchanged vector boson, which depicts the experimental realization of the electroweak unification.

- **Geometric scaling**
  Zuzana Gajdošová

  This talk presents on of the most important results in the field of small x physics obtained with data from HERA. This result was reported in Phys. Rev. Lett. 86 (2001) 596-599. The authors found that the proton structure function data measured at HERA over a large phase space in the (x,Q2) plane was not dependent on two, but on one variable for the region of small x. This phenomenon is known as geometric scaling. It introduces a large scale in the problem, known as the saturation scale, that separates the region in phase space where the density of partons is low – the dilute regime – from that region where the density is large: the saturation regime.

- **Measurements of VM production at HERA**
  Michal Broz

  In this presentation the production of vector mesons at HERA is reviewed. The review is based on the corresponding chapter of Rev. Mod. Phys. 86 (2014) 1037, where the main results obtained by the H1 and Zeus Collaborations in the field of photo and electro production of vector mesons are presented.
  The highlights include the mapping of the energy dependence of the exclusive photoproduction of vector meson for many different particles and the observation that at high energies these cross sections can be described by a power law, whose exponent depends on the mass of the particle. Another highlight is the dependence on the scale of the problem of the width of the distribution obtained from the dependence on transverse momentum of this cross section.

- **Geometric scaling in vector mesons**
  Marek Matas
  In XX, the authors explore the concept of geometric scaling for the exclusive electro production of vector mesons. To this aim, the authors introduced a framework for the dipole scattering amplitude which includes the possibility to consider processes where there is a momentum transfer in the target vertex. This generated a formalism, based on the concept of geometric scaling, depending on two parameters. This computation was successfully fitted to data from HERA, demonstrating that geometric scaling is also observed in vector meson production.

Session IV: Basic literature II

- **Energy dependent hot-spot model**
  Dagmar Bendová

  A model of the QCD structure of hadrons, where the relevant degrees of freedom are regions of high gluonic density, so-called hot spots, whose position in the impact parameter plane fluctuates event-by-event is presented. The main characteristic of the model, introduced in Phys. Lett. B766 (2017) 186-191, is that the number of hot spots depend on energy.

With this model it is possible to describe correctly data of exclusive and dissociative photoproduction of J/ψ as measured at HERA and at the LHC. The dissociative cross section is sensitive to fluctuations in the positions of the hot spots and its energy dependence provides a new, and striking, signature of saturation.

- **<u>Rho photoproduction off nulcei at RHIC and the LHC</u>**
  David Horák

  The STAR Collaboration at RHIC has studied for many years the coherent photoproduction of rho vector mesons in ultra-peripheral collisions of gold nuclei. These results cover collision energies in the laboratory system from 64 to 200 GeV. The latest results are discussed. They include the incorporation of the contribution of the omega vector mesons as well as the study of the Fourier transform of the transverse momentum distribution.

  At the LHC the ALICE Collaboration has studied the same process albeit at a lot larger energies, reaching 2.76 and 5.02 TeV per nucleon pair, and in collisions of lead ions. These results are also reviewed here.

- **<u>Charmonium photoproduction off nuclei at the LHC:</u>**
  Roman Lavička

  The ALICE Collaboration has studied the photonuclear production of J/ψ in ultra-peripheral collisions of lead ions at the largest energies ever reached in the laboratory. These measurements were the first of its kind at the LHC and demonstrated the feasibility of these studies at the LHC.

  The measurements demonstrated that could distinguish between scenarios of no, moderate and strong shadowing. The middle option being the one preferred by the measurements. Later on, the photonuclear production of ψ(2S) in ultra-peripheral collisions was also measured and confirmed that models incorporating moderate nuclear shadowing effects provided a good description of data.

- **<u>Data to come in the near future</u>**
  Michal Broz

  The process of taking the kind of data discussed in this meeting is quite long. It is important to be aware of the plans of the accelerator and the potential data sample that could be obtained in the future. The current official plans are presented here. They include the long shutdown (LS) two in 2019 and 2020. The data taking period of Run3 (2021-2023), the LS3 (2024-2026) and the Run4 data taking period (2027-2030). There are also plans for a LS4 and Run5 periods, but those are more uncertain being quite far in the future.

In the shorter term, the data taking scenario for this year, 2018, which includes 4 months of Pb-Pb collisions is discussed. It is expected that this data sample will a luminosity some factor of 5 to 10 larger than what has been collected up to date.

- **<u>b-dependent BK equation</u>**
  Marek Matas

  The Balistky-Kovchegov equation and its solution including the dependence on the impact parameter is discussed. The main problems in this case involve the appearance of an unphysical so-called Coulomb tail which appears, with the evolution in energy, at large impact parameters. This tail has its origin in the contribution of large dipoles.

  The current strategies devised to suppress large dipoles are discussed. These strategies are not ideal, and their drawbacks are presented. Among them is the fact that to describe data from HERA, it is needed to supplement by hand a so-called soft contribution that may amount to half of the cross section. Current plans of our group on how to improve this situation are discussed.