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SPD NICA

Expression of Interest Letter

In the NICA-SPD experiments it is proposed to perform measurements of cross-section asymmetries of the production of Drell-Yan (DY) lepton pairs in collisions of non-polarized, longitudinally and transversally polarized protons and deuterons. These asymmetries provide an access to all leading twist collinear and TMD PDFs of quarks and anti-quarks in nucleons. Measurements of similar asymmetries in production of J/Ψ and direct photons will be performed as well, using dedicated triggers. The set of these measurements will supply complete information for tests of the quark-parton model of nucleons at the QCD twist-two level with minimal systematic errors.

Description of the above mentioned measurements are very sensitive to the precise details of theoretical model, which should be used. In region of small transverse momenta of final particles, the TMD-factorization is used as conventional approach to describe spectra and polarization observables. In this approach, small transverse momenta of initial partons are taken into account in TMD PDFs, but off-shell initial-state effects in hard amplitudes are neglected. The results of TMD-factorization require some matching with predictions of fixed order calculations in the collinear factorization at large p_T , when p_T becomes the same order as hard scale ($Q = \sqrt{-q^2}$). This procedure introduces additional freedom into the model, and therefore treatment of the whole range of p_T in the framework of k_T -dependent factorization is desirable. Also, additional constraints which come from QED gauge-invariance of the hard-scattering coefficients with off-shell initial-state partons, provide certain relationships between TMD PDFs introduced in the "naive" TMD factorization. These relationships can be tested in the experiment. Recently, we have proposed so-called Parton Reggeization Approach (PRA), which can be used for the simultaneous description of the experimental data at all values of transverse momenta of final-state particles. PRA is based on high-energy factorization in the limit of multi-Regge kinematics and concept of Reggeization of QCD amplitudes. The cornerstone of PRA is L.N.Lipatov's effective theory of Reggeized gluons and Reggeized quarks. In this gauge invariant approach, initial partons, considered as Reggeized gluons or Reggeized quarks, are off-shell and have transverse momentum which is generated during the perturbative evolution of PDFs. TMD dependent PDFs for off-shell Reggeized partons are calculated from the collinear ones in the model based on modified multi-Regge limit of QCD scattering amplitudes. As it was recently shown, the extension of PRA to the level of next-to-leading order QCD calculations can be done. The self-consistent scheme of calculation of virtual and real corrections has

been proposed and specific two- and three-point vertex functions with off-shell Reggeized particles have been calculated.

Such a way, to understand the quark-gluon model of proton and dynamics of hard parton-parton interactions in QCD we should compare theoretical predictions obtained in different factorization schemes: NLO order of the collinear parton model, TMD-factorization approach and PRA. The last one will be taken in the LO and NLO approximations, dependently on studied process.

In particular, LO of PRA simultaneously predicts the p_T -dependence of all angular structure functions in the Drell-Yan pair production, starting from single universal unintegrated PDF. In contrast in the standard TMD factorization approach, e.g. in the case of collisions of unpolarized protons, different angular structure functions are related with unpolarized and Boer-Mulders TMD PDFs, the latter two are supposed to be independent of each-other. Reduction of number of independent TMD PDFs in PRA happens because the hard-scattering coefficient in our approach satisfies the QED Ward-identity even for the off-shell initial-state (Reggeized) quarks, which constrains the p_T -dependence of polarization of the produced virtual photon and therefore the p_T -dependence of angular structure functions.

The study of J/ψ production at low energies is interesting not only a sensitive test of parton model in its gluonic sector, but also from the point of view of studies of mechanism of J/ψ hadroproduction. In particular, the NLO CPM and LO PRA describe the p_T -spectra of prompt J/ψ mesons at LHC and Tevatron equally well, but produce the p_T -spectra with significantly different slope when the energy is lowered. At NICA energy the comparison of two models will be most efficient, because their results differ most significantly, but the parton model is still reasonably believed to be applicable.

We propose to perform theoretical calculations for asymmetries in the Drell-Yan's pair production as well as in production of J/Ψ and direct photons in the three discussed above approaches and implement our theoretical models in the relevant Monte Carlo generators for future use. This program could be realized in cooperation with scientific group from II Institute for Theoretical Physics of Hamburg University (charmonium production at the NLO level of collinear parton model) and SANC group from JINR (NLO calculation in the collinear parton model for production of prompt photons and Drell-Yan pairs). Taking into account the available time before the scheduled start of the experimental program at SPD, our group from Samara University can participate not only in theoretical calculations and simulation, but, after some training, also in experimental data analysis.

Main participants of the group:

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2. M. Nefedov, Candidate of science, scientist
3. A. Shipilova, Candidate of science, associate professor.
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Sincerely yours,

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