

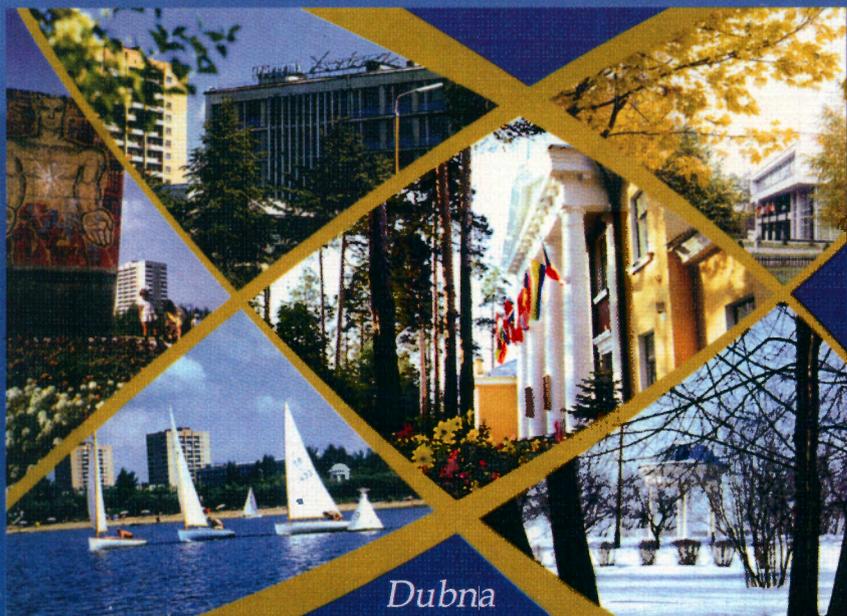
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BOOK OF ABSTRACTS



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**The 20th International Symposium on
Spin Physics**

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Book of Abstracts

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ядерных исследований
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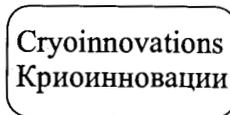
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Polarization phenomena in hadronic reactions

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A global analysis of polarization data is presented. The following data are included in the analysis: hyperon polarization, single-spin asymmetry and vector meson alignment in hadron-hadron, hadron-nucleus, nucleus-nucleus, lepton-nucleus and e^+e^- collisions. In total, 75 inclusive and 28 exclusive reactions with more than 6300 data points are used to reveal regularities in behavior of spin observables in the c.m. energy range from a few GeV up to 7 TeV. The data analysis is performed in the framework of an Effective Color Field (ECF) model, which assumes the creation of circular chromomagnetic and longitudinal chromoelectric fields by moving color quarks. The polarization phenomena arise due to interaction of quark chromomagnetic moment with non-uniform chromomagnetic field. Quark spin precession in a color field is taken into account. Focusing force of a circular field causes resonance like energy dependence of polarization observables [1-6]. Predictions for different reactions are given. Estimation of quark masses and their anomalous chromomagnetic moments from the global analysis are given for u , d , s , c and b quarks. The mass ratio of heavy (m_2) and light (m_1) constituent quarks obeys the simple relation: $\ln(m_2/m_1) = 4^{N-2}$, where N is a quark generation number. Detailed predictions are given for the polarization experiments at IHEP (SPASCHARM) [7], JINR (collider NICA) and BNL (collider RHIC). The dependence of the transverse single-spin asymmetry and hyperon polarization on the kinematic variables and the atomic weight of the projectile and target are obtained. Resonance like energy dependence is predicted for $\bar{\Lambda}$ hyperon polarization in proton-proton and nucleus-nucleus collisions.

References

1. V.V. Abramov, Phys. Atom. Nucl. **72**, 1872 (2009).
2. V.V. Abramov, J. Phys. Conf. Ser. **295** 012086 (2011).
3. V.V. Abramov, Proc. of the XIV Advanced Research Workshop on High Energy Spin Physics (DSPIN-11), edited by A.V.Efremov and S.V.Goloskokov, (Dubna, 2012) p. 21.
4. V.V. Abramov, Proc. of the XIII Advanced Research Workshop on High Energy Spin Physics (DSPIN-09), edited by A.V.Efremov and S.V.Goloskokov, (Dubna, 2010) p. 25, e-Print: arXiv:0910.1216 [hep-ph].
5. V.V. Abramov, Phys. Atom. Nucl. **70**, 2103 (2007).
6. V.V. Abramov, Proc. of the XII Advanced Research Workshop on High Energy Spin Physics (DSPIN-07), edited by A.V.Efremov and S.V.Goloskokov, (Dubna, 2008) p. 13, e-Print: arXiv:0711.0323 [hep-ph].
7. V.V. Abramov et al., J. Phys. Conf. Ser. **295** 012018 (2011).

QCD analysis of the semiinclusive COMPASS and HERMES data

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Analysis in the next to leading order (NLO) QCD of COMPASS and HERMES data on pion production in polarized semi-inclusive DIS experiments is performed in order to extract the first moments of the polarized parton distribution functions (PDFs) of valence and sea u and d quarks, truncated to the wide Bjorken x region $0.004 < x < 0.7$. To obtain the moments of valence polarized PDFs the alternative to traditional method is applied, which enables to extract them without any fitting procedure. As an input data pion difference asymmetries are used. The COMPASS and HERMES data are combined in two ways and two scenarios for the fragmentation functions (corresponding to broken and unbroken $SU_f(2)$ symmetry) are considered. Corrections due to weak Q^2 -dependence of asymmetries are also calculated. They turn out to be small, however, if an appropriate common scale Q_0^2 is chosen.

Having in disposal the first moments of valence distributions, we estimate light sea quark contributions to the proton spin. To this end two different procedures are applied. The first uses values of $\Delta_{1q} + \Delta_{1\bar{q}}$ from the analysis of inclusive data. The second is based on application of Bjorken and $SU_f(3)$ sum rules. Both procedures lead to the conclusion that these contributions are compatible with zero within the errors.

High precision measurements of the pion-proton elastic scattering and kaon-lambda production in the EPECUR experiment

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Study of the pion-nucleon scattering can produce a rich information on the dynamics of the strong interaction and baryon spectroscopy. The EPECUR collaboration is aimed at the research of baryon resonances in the second resonance region via pion-proton elastic scattering and kaon-lambda production. Our main interest is in search for neutron-like exotic states like $N(1685)$, which was seen in $\eta\pi$ photoproduction off neutron and quoted in the recent PDG issue [1] with 1-star status. The interest to this search was recently revived by a new CLAS paper [2], where θ^+ was observed in the interference with ϕ -meson.

The experiment features high statistics and better than 1 MeV resolution in the invariant mass thus allowing searches for narrow resonances with the coupling to the πp channel as low as 5%. The experiment is of "formation" type, i.e. the resonances are produced in s-channel and the scan over the invariant mass is done by the variation of the incident pion momentum which is measured with the accuracy of 0.1% with a set of 1 mm pitch proportional chambers located in the first focus of the beam line. The reaction is identified by a magnetless spectrometer based on wire drift chambers with a hexagonal structure. For the reaction of kaon-lambda production ($\pi^- p \rightarrow K\Lambda$) the Λ polarization will be measured with unprecedented precision via its decay $\Lambda \rightarrow \pi^- p$, giving a valuable additional information.

The measurements started in 2009 with the setup optimized for elastic pion-proton scattering. With 3 billions of triggers already recorded the differential cross section of the elastic πp -scattering on a liquid hydrogen target in the region of the diffractive minimum is measured with statistical accuracy about 1% in 1 MeV steps in terms of the invariant mass. The talk covers the current status, preliminary results and future plans.

References

1. J. Beringer *et al.* (Particle Data Group), Phys. Rev. **D86**, 010001 (2012)
2. M.J. Amaryan *et al.* Phys. Rev. **C85**, 035209 (2012)

Designation of SIDIS data in determining the polarized sea-quark distributions and their moments

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Generally speaking, Polarized inclusive DIS data can not distinguish u , d and s from \bar{u} , \bar{d} and \bar{s} , but $\delta s = \delta \bar{s}$ is well determined and all the unbroken symmetry analysis yield a negative value of it for any x in measured region. In the current analysis we employ SIDIS data which causes a flavor decompositions of the polarized sea quarks, and the light antiquark polarized densities \bar{u} and \bar{d} are determined separately. For the strange sea quark distribution we added a new term to initial parameterization to let a sign changing for $\delta s = \delta \bar{s}$. Although the separated determination of s and \bar{s} was done recently by COMPASS[1], there was shown that there is no considerable difference between them and also the large error of $x(\delta s - \delta \bar{s})$ measurement allows us to conclude the assumption of $\delta s = \delta \bar{s}$. The first moment of valence and sea distributions of the presented model truncated to the range of SMC98, HERMES05 and COMPASS07 experiments[2-4] is also calculated and all the final results are in very good agreement with other theoretical models[5,6] and recent experimental data.

References

1. M. G. Alekseev et al. [COMPASS Collaboration], Phys. Lett. B **693**, 227 (2010).
2. SMC Collaboration, B. Adeva et al., Phys. Lett. B **420**, 180 (1998).
3. A. Airapetian et al. [HERMES Collaboration], Phys. Rev. D **71**, 012003 (2005).
4. M. Alekseev et al. [COMPASS Collaboration], Phys. Lett. B **660**, 458 (2008).
5. D. de Florian, R. Sassot, M. Stratmann and W. Vogelsang, Phys. Rev. D **80**, 034030 (2009).
6. E. Leader, A. V. Sidorov and D. B. Stamenov, Phys. Rev. D **82**, 114018 (2010).

Search for Electric Dipole Moment in ^{129}Xe Atom Using a Nuclear Spin Oscillator

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What we know from laboratory experiments about particles and their interactions are surprisingly well described by the standard model (SM) of elementary particles. Nevertheless, most of us cannot avoid feeling dissatisfaction with this model, because there are a number of questions which the model is unable to answer, such as why matter so overwhelms over antimatter in the Universe [1]. The permanent electric dipole moment (EDM) serves as an exclusively suited observable to look for flaw, if any, of the SM. This is by virtue of the fact that this flavor-diagonal observable violates T and hence CP invariance. EDMs are being or planned to be searched for in various sites: in neutron, paramagnetic atoms, diamagnetic atoms [2], molecules, and even in charged particles such as muon, proton, deuteron and ions.

We aim at searching for an EDM in the diamagnetic atom ^{129}Xe . The EDM is deduced from observed frequency change upon reversal of an E field. We use a novel method with a nuclear spin oscillator [3], in order to realize long spin coherence time for ^{129}Xe , as illustrated in Fig. 1. Operation of the spin oscillator and recent developments towards frequency stabilization, the incorporation of a ^3He co-magnetometer, and cell temperature control will be discussed in the talk. Until present, we have achieved a frequency precision of $dn = 7.9$ nHz, which corresponds to an expected sensitivity of $8 \times 10^{28} e$ cm to EDM for an electric field of $E = 10$ kV/cm.

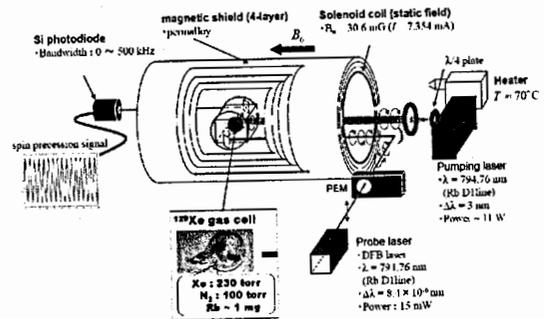


Fig. 1

References

1. M. Trodden, Rev. Mod. Phys. **71**, 1463 (1999).
2. W.C. Griffith et al, Phys. Rev. C **82**, 015501 (2010).
3. A. Yoshimi et al., Phys. Lett. A **376**, 1924 (2012).

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Polarization phenomena in hadronic reactions

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A global analysis of polarization data is presented. The following data are included in the analysis: hyperon polarization, single-spin asymmetry and vector meson alignment in hadron-hadron, hadron-nucleus, nucleus-nucleus, lepton-nucleus and e^+e^- collisions. In total, 75 inclusive and 28 exclusive reactions with more than 6300 data points are used to reveal regularities in behavior of spin observables in the c.m. energy range from a few GeV up to 7 TeV. The data analysis is performed in the framework of an Effective Color Field (ECF) model, which assumes the creation of circular chromomagnetic and longitudinal chromoelectric fields by moving color quarks. The polarization phenomena arise due to interaction of quark chromomagnetic moment with non-uniform chromomagnetic field. Quark spin precession in a color field is taken into account. Focusing force of a circular field causes resonance like energy dependence of polarization observables [1-6]. Predictions for different reactions are given. Estimation of quark masses and their anomalous chromomagnetic moments from the global analysis are given for u , d , s , c and b quarks. The mass ratio of heavy (m_2) and light (m_1) constituent quarks obeys the simple relation: $\ln(m_2/m_1) = 4^{N-2}$, where N is a quark generation number. Detailed predictions are given for the polarization experiments at IHEP (SPASCHARM) [7], JINR (collider NICA) and BNL (collider RHIC). The dependence of the transverse single-spin asymmetry and hyperon polarization on the kinematic variables and the atomic weight of the projectile and target are obtained. Resonance like energy dependence is predicted for $\bar{\Lambda}$ hyperon polarization in proton-proton and nucleus-nucleus collisions.

References

1. V.V. Abramov, *Phys. Atom. Nucl.* **72**, 1872 (2009).
2. V.V. Abramov, *J. Phys. Conf. Ser.* **295** 012086 (2011).
3. V.V. Abramov, *Proc. of the XIV Advanced Research Workshop on High Energy Spin Physics (DSPIN-11)*, edited by A.V.Efremov and S.V.Goloskokov, (Dubna, 2012) p. 21.
4. V.V. Abramov, *Proc. of the XIII Advanced Research Workshop on High Energy Spin Physics (DSPIN-09)*, edited by A.V.Efremov and S.V.Goloskokov, (Dubna, 2010) p. 25, e-Print: arXiv:0910.1216 [hep-ph].
5. V.V. Abramov, *Phys. Atom. Nucl.* **70**, 2103 (2007).
6. V.V. Abramov, *Proc. of the XII Advanced Research Workshop on High Energy Spin Physics (DSPIN-07)*, edited by A.V.Efremov and S.V.Goloskokov, (Dubna, 2008) p. 13, e-Print: arXiv:0711.0323 [hep-ph].
7. V.V. Abramov *et al.*, *J. Phys. Conf. Ser.* **295** 012018 (2011).

Λ Hyperon Polarization in pC reaction at 10 GeV/c

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Review of the latest theoretical and experimental work on the polarization of Λ -hyperons in the inclusive reactions $p + A$ and $A + A$. New result of the Λ -hyperons polarization have measured with $4p$ geometry in the reaction $p + C$ at a momentum of 10 GeV/c. Then a comparison with the polarization of Λ -hyperon emitted at the backward angles.

Determination of polarized parton densities from a QCD analysis

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The results of our new QCD analysis of helicity parton distributions of the nucleon up to NLO order will be presented. Doing a QCD fit on newest inclusive and semi-inclusive polarized deep inelastic scattering data, we are able to extract polarized structure function of nucleons by choosing new parton distributions at input scale Q_0^2 . Particularly we have calculated parton distributions in SU(2) and SU(3) symmetry breaking scenario and the results are in good agreement with the experimental data and the most precise theoretical model obtained by DSSV09 and LSS10.

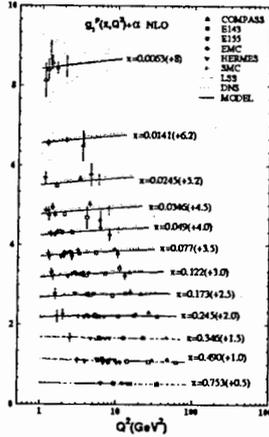


Figure 1: The polarized structure function g_1^p as function of Q^2 in intervals of x .

References

1. S. Atashbar Tehrani and A. N. Khorramian, JHEP.0707, 048 (2007) [arXiv:0705.2647 [hep-ph]].
2. A. N. Khorramian, S. Atashbar Tehrani, S. Taheri Monfared, F. Arbabifar and F. I. Olness, Phys. Rev. D **83** (2011) 054017 [arXiv:1011.4873 [hep-ph]].
3. S. Atashbar Tehrani, A. N. Khorramian, S. Taheri Monfared and F. Arbabifar, AIP Conf. Proc. **1374**, 391 (2011).
4. F. Arbabifar, A. N. Khorramian, S. Taheri Monfared and S. Atashbar Tehrani, Int. J. Mod. Phys. A **26**, 625 (2011).
5. A. N. Khorramian, S. Atashbar Tehrani, F. Olness, S. Taheri Monfared and F. Arbabifar, Nucl. Phys. Proc. Suppl. **207-208**, 65 (2010).

Measurement of transverse momentum distributions with CLAS and CLAS12

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The detailed understanding of the orbital structure of partonic distributions, encoded in Transverse Momentum Dependent (TMD) parton distributions, have been widely recognized as one of the key objectives of the JLab 12 GeV upgrade project and driving force behind construction of the Electron Ion Collider. The extraction of TMDs from different single and double spin azimuthal asymmetries is hindered by absence of reliable and model independent procedure for flavor decompositions of underlying TMDs. The various assumptions involved in preliminary extraction of TMDs from available data do not allow a credible estimate of systematic errors and as a result hinder a realistic projection of the statistics required for the extraction of relevant TMDs.

In this contribution we discuss a model-independent extraction of Fourier transforms of TMD distributions from latest CLAS data on polarized hydrogen.

Studies of transverse structure of the proton at JLab and JLab12

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In recent years parton distributions, describing longitudinal momentum, helicity and transversity distributions of quarks and gluons, have been generalized to account also for transverse degrees of freedom. Two new sets of more general distributions, Transverse Momentum Distributions (TMDs) and Generalized Parton Distributions (GPDs) were introduced to describe transverse momentum and space distributions of partons. Great progress has been made since then in measurements of different Single Spin Asymmetries (SSAs) in semi-inclusive and hard exclusive processes providing access to TMDs and GPDs respectively. Facilities world-wide involved in studies of the 3D structure of the nucleon include HERMES at HERA, CLAS and Hall-A at JLab and COMPASS at CERN. Significant progress has been achieved recently in lattice measurements of TMD moments. Studies of TMDs and GPDs are also one of the main driving forces of the JLab 12 GeV upgrade project.

In this talk we present an overview of the latest developments in studies of TMDs and GPDs and discuss newly released results, ongoing activities, as well as some future measurements at JLab12.

SANE experiment

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The Spin Asymmetries of the Nucleon Experiment (SANE) is a measurement of the parallel, A_{para} , and near-perpendicular, A_{80} , double spin asymmetries in inclusive polarized electron scattering off the polarized proton. The experiment was performed in Hall-C at the Thomas Jefferson National Accelerator Facility. The scattered electrons were detected using the Big Electron Telescope Array, BETA, which was centered at 40° and covered a large solid angle. The data was taken at two beam energies of 4.7 and 5.9 GeV and covered $2.5 \text{ GeV}^2 < Q^2 < 6.5 \text{ GeV}^2$. The proton's spin asymmetries, A_1 and A_2 , and the spin structure functions of the proton, g_1 and g_2 , are extracted from the measured A_{para} and A_{80} . The measurements are in a range of Bjorken x_B , $0.3 < x_B < 0.8$, where extraction of the twist three matrix element d_2^p (an integral of g_1 and g_2 weighted by x_B^2) is most sensitive.

Lattice QCD for Spin Physics

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Lattice QCD results on the distribution of the spin of the proton among its constituents and of its decomposition into quark spins and angular momenta will be reviewed. Recently, significant progress has been made in determining the individual sea quark contributions. This became possible due to advances in techniques to compute Green functions containing disconnected quark lines. In particular, the strangeness contribution to the proton spin was found to be smaller than previously expected. Comments on future prospects will be given.

Perspectives of the study of charmonium and exotics in experiments using antiproton beam with momentum ranging from 1 to 15 GeV/c

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The study of strong interactions and hadronic matter in the process of antiproton-proton annihilation seems to be a perspective nowadays. The research of charmonium, charmed hybrid and tetraquark spectra and their main characteristics (mass, width and branch ratios) in experiments using antiproton beam with momentum ranging from 1 to 15 GeV/c, are promising to understand the dynamics of quark interactions at small distances. Charmonium spectroscopy is a good testing tool for the theories of strong interactions: QCD in perturbative and non-perturbative regimes, LQCD and QCD inspired phenomenological potential models.

Nowadays the scalar 1P_1 , 1D_2 and vector 3P_1 , 3D_1 , charmonium states and higher lying scalar 1S_0 and vector 3S_1 charmonium states are poorly investigated. The domain above $D\bar{D}$ threshold equal to 3.73 GeV/c² is badly studied. According to the contemporary quark models namely in this domain, the existence of charmed hybrids with exotic ($J^{PC} = 0^{+-}, 1^{+-}, 2^{+-}$) and non-exotic ($J^{PC}=0^{++}, 1^{++}, 2^{++}, 1^{--}, 1^{--}$) quantum numbers as charged and neutral tetraquarks is expected [1, 2].

The elaborate analysis of spectrum of charmonium and charmed hybrids was carried out, and the attempts to interpret a great quantity of experimental data above $D\bar{D}$ threshold were considered. Using the combined approach based on the quarkonium potential model and model of confinement on the three-dimensional sphere embedded into four-dimensional Euclidian space, new radial excited states of charmonium and charmed hybrids in the mass region above $D\bar{D}$ threshold are expected to exist. But much more data on different decay modes are needed for deeper analysis. These data can be derived directly from PANDA experiment with its high quality antiproton beam. The advantage of antiproton beam consists in intensive production of particle-antiparticle pairs which is observed in antiproton-proton annihilation. This fact allows one to carry out spectroscopic research with good statistics and high accuracy.

Especially attention is given to the new states with the hidden charm discovered recently [2]. The experimental data from different collaborations were carefully studied. Most of these states were observed above $D\bar{D}$ threshold in one definite channel. New particles were produced from B -meson decays and in electron-positron or two-photon collisions. Their interpretation is far from been obvious nowadays [2]. Some of these states can be interpreted as higher lying states of charmonium. This treatment seems to be perspective and needs to be carefully verified in PANDA experiment at FAIR.

References

1. PANDA Collaboration // Physics Performance Report 2009. P.63.
2. N.Brambilla *et al.* // European Physical Journal C 71:1534 2011. P.1.

Status and recent developments in $NN \rightarrow NN\pi$

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We study pion production in the reaction $NN \rightarrow NN\pi$ at low energies in chiral EFT. We review the status of the theory in the isospin conserving case [1-3] and discuss charge symmetry breaking effects in the same framework [4].

A precondition for the success of the study is the possibility to compare directly, that is on the level of the individual partial wave amplitudes, the results of chiral EFT with experimental data. Recent measurements of $\bar{p}p \rightarrow (pp)_s \pi^0$ and $\bar{p}n \rightarrow (pp)_s \pi^-$ at $T_{\text{lab}}=353$ MeV at COSY provide a great step towards this goal. In this talk we focus on the details of the partial wave analysis of these data [5-6]. We demonstrate that the high-precision data of these experiments have allowed the determination of the partial wave amplitudes up to pion d-waves through a careful use of the Watson theorem. Specifically, the p-wave pion production amplitudes can be used to pin down the role of the short-range physics encoded in the $4N\pi$ low-energy constant (LEC d). Apart from pion production, this LEC contributes to the three-nucleon force, to electroweak processes as well as to the low-energy reactions involving photons.

References

1. V. Lensky et al., *Eur. Phys. J. A* **27**, 37 (2006).
2. V. Baru et al., *Phys. Rev. C* **80**, 044003 (2009).
3. A. A. Filin et al., *Phys. Rev. C* **85**, 054001 (2012).
4. A. A. Filin et al., *Phys. Lett. B* **681**, 423 (2009).
5. D. Tsirkov et al. [COSY-ANKE Collaboration], *Phys. Lett. B* **712**, 370 (2012)
6. S. Dymov et al. [COSY-ANKE Collaboration], *Phys. Lett. B* **712**, 375 (2012)

Impact of Three-Dimensional Polarization Profiles on Spin-Dependent Measurements in Colliding Beam Experiments

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We derive the effect of 3-dimensional polarization profiles on the measured polarization in polarimeters, as well as the observed polarization and the polarization-weighted luminosity (figure of merit) in single and double spin measurements in colliding beam experiments. Applications to RHIC are discussed [1].

References

1. W.Fischer and A.Bazilevsky, *Phys. Rev. Spec. Topics - Accel. and Beams*, **15**, 041001 (2012).

Results from the COMPASS Nucleon Structure Program

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The COMPASS collaboration at CERN is studying the structure of the nucleon since 2002, with emphasis on spin. The experimental technique is fixed-target muon-nucleon scattering in either the quasi-real photo-production or the DIS regime. The beam is longitudinally polarised. The target, either proton or deuteron, is longitudinally or transversely polarised.

In the longitudinal case, semi-inclusive double spin asymmetries allow us to access longitudinally polarised PDFs. Our latest results of the LO extraction of ΔG are shown and our ongoing analyses of NLO corrections are presented. Concerning the extraction of the other parton flavours, COMPASS has previously demonstrated the decisive role played by fragmentation functions, and our research focus has shifted to the study of fragmentation. The current status of this study is presented.

In the transverse and unpolarized cases, the measurement of the azimuthal modulations of the produced hadron yield gives access to transversity and to a rich phenomenology of transverse momentum dependent distributions (TMDs). Our latest results along this line are also shown.

Spin transfer to Λ and $\bar{\Lambda}$ hyperons in deep inelastic scattering at HERMES

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Spin structure of Λ (and other) hyperons is still debatable. Experimentally, quark spin degrees of freedom in a hyperon can be accessed by measurement of the spin transfer in deep inelastic scattering of polarized leptons. In this talk study of spin transfer to the Λ and $\bar{\Lambda}$ hyperons in the HERMES experiment is summarized. The measurements were performed with the help of the HERMES spectrometer using a 27.6 GeV longitudinally polarized positron (or electron) beam of the HERA accelerator and a polarized or unpolarized hydrogen or deuterium gas target with a storage cell. The data accumulated during the whole HERMES data taking period were analyzed. After optimization of background suppression cuts, a sample with 76 000 Λ and 11 000 $\bar{\Lambda}$ events, essentially surpassing preliminary HERMES results [1,2], was selected. All three components of the spin transfer treated as a vector were extracted from the data sample using the moment method. As far as the beam polarization was periodically reversed the spectrometer acceptance did not affect the extracted asymmetries, and therefore, no Monte Carlo simulation of the detector was involved in the analysis. Possible false asymmetries were controlled with the help of Ks and hadron pairs subsamples. For Λ hyperons, a longitudinal component directed along the virtual photon momentum in the Λ rest frame is found to be $D_{LL}^{\Lambda} = 0.19 \pm 0.04_{\text{stat}} \pm 0.02_{\text{sys}}$ while the two other (transverse) components are compatible with zero. For $\bar{\Lambda}$ hyperons, all components are compatible with zero within statistical error bar of ± 0.1 . The obtained results are in a good agreement with NOMAD [3] and recent COMPASS [4] experiments at moderate values of x_F Feynman variable, while the HERMES and COMPASS results disagree at larger x_F ($x_F > 0.4$). Positive and statistically significant value of D_{LL}^{Λ} can be interpreted in favor of significant positive contribution of the light u and d quarks to the Λ spin and sizeable SU(6) symmetry breaking in the quark distributions of the Λ [5].

References

1. A.Airapetian et al. (HERMES collaboration), Phys.Rev. D74, 072004 (2006)
2. A.Airapetian et al. (HERMES collaboration), Phys.Rev. D64, 112005 (2001)
3. P.Astier et al. (NOMAD collaboration), Nucl.Phys. 588, 3 (2000)
4. M.Alekseev et al (COMPASS collaboration), Eur.Phys.J. C64, 171-179 (2009)
5. C.Boros and J.T. Londergan, Phys.Rev. D61, 014007 (2000)

Polarized Ion Sources: Status and Perspectives

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Modern polarized ion sources generate polarized ion beams with high intensity and polarization. Mainly, atomic beam-type and optically pumped polarized ion sources are used to deliver polarized ion beams to accelerators. Principles of both methods are outlined in the paper. At BNL, an optically pumped polarized ion source (OPPIS) is routinely used to deliver beam of polarized negative hydrogen ions to RHIC accelerator complex. The BNL OPPIS produces polarized negative hydrogen (H^-) ion beam with peak current of $\sim(0.5-1.0)$ mA, polarization of 80-90% at rep. rate of 1 Hz [1]. The OPPIS upgrade assumes use of high-brightness injector of neutral hydrogen atomic beam with energy of ~ 5 keV instead of an ECR ion source with goal to increase peak polarized H^- ion beam intensity to level of ~ 10 mA [1]. Additionally, a new type OPPIS of polarized $^3He^{++}$ ions is developed for RHIC accelerator [2]. Optical pumping is used also for production of polarized radioactive ions such as $^8Li^+$ and other elements at TRIUMF [3]. Atomic beam-type source of polarized ions (ABPIS) with colliding beam ionizer delivers up to $5 \cdot 10^{12}$ H^- or D^- ions per 20 ms pulse for COSY at Jülich [4]. Polarization of ion beam injected into COSY reaches 90%. The polarized D^- ion beam is delivered to the COSY ring in fifteen different polarization combinations due to use of different high-frequency transitions. ABPIS with resonant charge-exchange ionizer for NICA accelerator complex is under construction at JINR in collaboration with INR RAS and IUCF [5]. The source is based on developments made at INR RAS [6] where method for production of polarized negative and positive hydrogen ions via nearly resonant charge-exchange reaction between polarized hydrogen atoms with thermal energy and unpolarized deuterium ions in plasma has been developed. Possible improvements of the ABPIS connected with further study of atomic beam formation and conversion of polarized atoms into polarized ions are considered.

References

1. A. N. Zelenski et al., Proc. Of 14th International Workshop on Polarized Sources, Targets and Polarimetry (PSTP 2011), 12-16 September 2011, St.Petersburg, Russia, eds. K. Grigoryev, P. Kravtsov and A. Vasilyev, ISBN 978-5-86763-282-3, (2011), pp. 83-86.
2. J. Maxwell and R. Milner, this Symposium.
3. C. D. P. Levy, Proc. Of XIIth International Workshop PSTP 2007, BNL, USA, 10-14 September, 2007, AIP Conf. Proc. 980 (2008), p. p. 273-282.
4. R. Gebel, this Symposium.
5. V. Fimushkin et. al., this Symposium.
6. A. S. Belov, Proc. Of XIIth International Workshop PSTP 2007, BNL, USA, 10-14 September, 2007, AIP Conf. Proc. 980 (2008), p. p. 209-220.

COMPASS results on transverse spin asymmetries in identified two-hadron production in SIDIS

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For each quark flavour q three independent parton distribution functions (PDF) are necessary to describe the nucleon at twist-two level, the quark distribution $f_1^q(x)$, the helicity distribution $g_1^q(x)$ and the transversity distribution $h_1^q(x) = q_q^{\uparrow\uparrow}(x) - q_q^{\uparrow\downarrow}(x)$; where $\uparrow\uparrow$ means quark spin parallel and $\uparrow\downarrow$ antiparallel to the spin of the transversely polarized nucleon. The transversity distribution function is chiral-odd and therefore not accessible in deep inelastic scattering (DIS). However, $h_1^q(x)$ can be observed in semi-inclusive DIS in combination with another chirally odd function like the interference fragmentation function (IFF) $H_{1,q}^a$ in two-hadron production, which is the subject of this contribution.

The 160 GeV/c polarized μ^+ beam of CERN's M2 beamline allows COMPASS to investigate the spin structure of the nucleon using polarized solid state targets. In this contribution a comparative overview of the COMPASS results for the azimuthal asymmetries in two-hadron production is given. This includes the results on a polarized deuteron target (6LiD) from the data taken in the years 2002-04, as well as the first data set on a transversely polarized proton target (NH_3) taken in the year 2007 and a data set taken on the same target during the full year 2010 to increase precision. The asymmetries for h^+h^- hadron pairs from these data sets will be compared to recent model predictions and the corresponding results from HERMES. An extraction of $h_1^q(x)$ using the two-hadron IFF $H_{1,q}^a$ has been carried out for the 2007 data. In addition the azimuthal asymmetries of identified hadron pairs from the 2010 data will be presented for the first time.

Double Polarization Experiments at JLAB Using the Hall B FROST and HD-ICE Polarized Targets and CLAS

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A significant portion of the Hall B experimental program at Jefferson Lab is focused on light baryon and meson spectroscopy. Meson photoproduction experiments are an essential part of this program. The CEBAF Large Acceptance Spectrometer (CLAS) and the availability of circularly and linearly polarized tagged photon beams and frozen spin polarized targets provide unique conditions for this type of experiments. This combination of experimental tools gives the CLAS Collaboration the opportunity to measure double polarization observables for different pseudoscalar meson photoproduction processes. For the first time a nearly complete set of measurements is possible and will facilitate model independent extraction of the reaction amplitude. An overview of the experimental program and its status, together with recent results will be presented.

Polypropylene Track Membranes –a Promising Material for Thin Targets with Polarized Protons

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For the last years, in order to create targets with polarized hydrogen nuclei (protons or deuterons), polymers have often been used as a material of a working substance [1]. These materials represent solid substances that essentially simplify their use as targets and open new experimental opportunities. Polymers with the general formula $(-CH_2-)_n$ and $(-CD_2-)_n$ due to maximal among solid organic substances are especially interesting to the contents of hydrogen atoms. The target as films with the thickness less than 10 μm with the advanced surface is of interest for some experiments in nuclear physics. In this paper with the purpose of using a working substance of a polarized target, suggested is a new material – polypropylene track membranes produced by irradiation of polypropylene films by a high-energy heavy ion beam and a subsequent chemical etching of the latent tracks of these particles [2]. In the present experiments, membranes with an effective pore diameter of 0.40 μm (pore density 10^7 cm^{-2}) and 0.15 μm (pore density $2 \times 10^8 \text{ cm}^{-2}$) that were produced from polypropylene film Torayfan T2372 (Toray Co., Japan) with a thickness of 10.0 μm were used. In order to provide the membranes with the paramagnetic properties required for realization of the process of dynamic polarization of nuclei, a nitroxyl radical 2,2,6,6-tetramethyl-piperidine-1-oxyl (TEMPO) was introduced into the sample by the method of thermal diffusion. By the electronic paramagnetic resonance method information was received about paramagnetic centers in the polymeric matrix of the membranes, a concentration of the nitroxyl radical and a rotary mobility of the spin probe in them were determined. It is shown that the matrix of the polypropylene track membrane is quite a good solvent for nitroxyl radical – a value of concentration of the radical in them (that depends on conditions of thermal diffusion) can be high enough. Thus the performed studies allow us to consider the polypropylene track membranes with stable radical TEMPO as a perspective material for thin targets with the polarized protons. However, the final conclusion about efficiency of their use in targets can be made after realization of the research on the dynamic polarization of protons in these materials.

References

1. E.I. Bunyatova, Nucl. Instr. and Meth. A, 2004. vol. 526, pp. 22-27 (2004).
2. L.I. Kravets et al., High Energy Chemistry, vol. 31, pp. 89-93 (1997).

What tells Gravity on the shape and size of the electron

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The experimentally observable parameters of the electron (mass m , spin s , charge e and μ) indicate unambiguously that electron creates asymptotically the Kerr-Newman (KN) gravitational field. So far as the spin/mass ratio of the electron is extremely high, the black hole horizons disappear, and the Kerr singular ring of the Compton radius $a = \hbar/2m$ turns out to be naked. Therefore, a topological defect of the space-time appears at the large distance from the electron, and this singularity should be regularized. The long-term investigations showed that the regularized KN source takes the form of a chiral soliton model, core of which forms a vacuum bubble confining Higgs field in a superconducting pseudovacuum state, see[1,2]. Consistency with the external Kerr-Newman solution determines unambiguously the shape and size of this bubble as an oblate disk of the Compton radius $a = \hbar/2m$ with the 'classical' thickness $e^2/2m$. Matter of the bubble consists of the relativistically rotating 'false vacuum' and it cannot be observed by scattering, while the most hard part of the bubble forms a closed relativistically rotating (heterotic) string positioned at the edge of the disk [2,3,4]. It was argued in [4], that the *pointlike 'image' of the electron appears as a result of the Lorentz contraction of this string, caused by its relativistic rotation*, [3]. It is expected that the experiments with diffractive and non-forward Compton scattering of the polarized electrons [4] should be very important, since they could reveal the string-like form and the Compton size of the electron [5].

References

1. A. Burinskii, J. Phys. A: Math. Theor. **43** 392001 (2010), [arXiv: 1003.2928].
2. A. Burinskii, Journ. of Phys: Conf. Series, **343** 012019 (2012).
3. A. Burinskii, Journ. of Phys: Conf. Series, **361** 012032 (2012).
4. A. Radyushkin, Phys. Rev. D **56** 5524 (1997), [hep-ph/9704207].
5. A. Burinskii, Proceed. of the XIV Advanced Research Workshop on High Energy Spin Physics (DSPIN-11), eds. A.V. Efremov and S.V. Goloskokov, Dubna, 2012, p.391.

Cusped light-like Wilson loops, rapidity evolution of TMDs and geometry of the loops space

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We discuss a relationship of geometrical properties of the loops space described by means of the Polyakov-Makeenko-Migdal (PMM) approach with energy/rapidity evolution of cusped Wilson loops on the light-cone. Analysis of the dynamical equations for such Wilson loops calls for careful treatment of the emergent ultraviolet and rapidity singularities which make them non-multiplicatively-renormalizable. To this end, we propose to consider the renormalization properties of the light-cone cusped Wilson loops from the point of view of the universal geometrical PMM approach that corresponds to the Dyson-Schwinger set of equations for the loop space. We discuss the relevance of the PMM equations to energy/rapidity evolution of some phenomenologically significant objects, e.g., TMD and collinear PDFs, etc.

ELECTROMAGNETIC SOLITON-PARTICLE WITH SPIN AND MAGNETIC MOMENT

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The concept of particle as a soliton solution of nonlinear electrodynamics is considered [1,2]. This particle solution can have the basic characteristics of elementary particle such that mass, spin, charge, and magnetic moment [3,4].

Here we continue to consider the soliton-particle solution of Born-Infeld nonlinear electrodynamics having ring singularity [5-7].

We consider the problem for finding the appropriate solution having static and quick-oscillating time-periodic parts.

The static part gives charge and magnetic moment of the particle. The static part gives a part of mass and a part of spin of the particle for the solution with the quick-oscillating part.

The quick-oscillating or wave part gives the quantum or wave behavior of the particle. But the quick-oscillating part gives also a contribution to mass and spin of the particle because the wave part has energy and angular momentum densities. Thereby we can have the connection between the quantum properties of the particle and its energy characteristics that is mass and spin.

We search the appropriate solution in series form for toroidal coordinates.

The obtained relations for characteristics of soliton-particle is discussed.

References

1. A.A. Chernitskii, J. High Energy Phys., **1999(12)**, Paper 10 (1999).
2. A.A. Chernitskii, Encyclopedia of Nonlinear Science, ed. A. Scott, (New York and London, 2004) p. 67.
3. A.A. Chernitskii, Proc. XI Advanced Research Workshop on High Energy Spin Physics (DSPIN-05), eds. A.V. Efremov and S.V. Goloskokov, (Dubna, 2006) p. 234.
4. A.A. Chernitskii, Proc. The 17-th International Spin Physics Symposium (SPIN2006), eds. K. Imai *et al.*, AIP Conference Proceedings **915**, (Melville, New York, 2007) p. 264.
5. A.A. Chernitskii, Proc. XII Advanced Research Workshop on High Energy Spin Physics (DSPIN-07), eds. A.V. Efremov and S.V. Goloskokov, (Dubna, 2008) p. 433.
6. A.A. Chernitskii, Proc. XIII Advanced Research Workshop on High Energy Spin Physics (DSPIN-09), eds. A.V. Efremov and S.V. Goloskokov, (Dubna, 2010) p. 443.
7. A.A. Chernitskii, Proc. XIV Advanced Research Workshop on High Energy Spin Physics (DSPIN-11), eds. A.V. Efremov and S.V. Goloskokov, (Dubna, 2012) p. 395.

COMPASS-II

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On 1 December 2010 the proposal for a COMPASS-II Experiment [1] has been approved by the CERN Research Board. After almost ten years of important results achieved by the COMPASS Collaboration in both nucleon spin physics, with the use of muon beam, and hadron spectroscopy, using hadron beams, this second phase offers now a unique chance to address in the very near future newly opened QCD-related challenges, at very moderate upgrade cost, thanks to the versatility of the COMPASS apparatus. This implies mainly study of:

- chiral perturbation theory (ChPT), by measuring the pion polarizability through Primakoff reaction;
- generalized parton distributions (GPDs), by measuring exclusive deeply virtual compton scattering (DVCS) and hard exclusive meson production;
- transverse momentum dependent parton distributions (TMDs) in single-polarised pion-induced Drell-Yan muon production and in SIDIS on a liquid hydrogen target (in parallel to DVCS).

We have just entered this exciting second phase of COMPASS Experiment with the 2012 run almost entirely dedicated to Primakoff reaction measurement, but which also includes a test of DVCS measurements. COMPASS-II will then proceed with the Drell-Yan programme in 2014, and finally with the GPD programme in 2015 and 2016.

An overview of the COMPASS-II proposal will be presented, with a main focus on the new upcoming investigation of the nucleon structure through the Drell-Yan and GPD programmes.

References

1. COMPASS Collab., F. Gautheron *et al.*, CERN-SPSC-2010-014, SPSC-P-340, 17 May 2010

Polarization of Stored Beam by Spin Filtering at COSY

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Polarized antiprotons would open a new window in hadron physics, providing access to a wealth of single and double spin observables in proton-antiproton interactions.

The PAX Collaboration [1] aims to perform the first ever measurement of the spin-dependence of the proton-antiproton cross-section at the AD ring at CERN [2].

The spin-dependence of the cross-section could in principle be exploited by the spin-filtering technique, in order to obtain an intense beam of polarized antiprotons in a dedicated storage ring.

As a preparatory phase to the experimentation at AD, the PAX Collaboration has performed a spin-filtering experiment with protons at the COSY-ring in Jülich (Germany), aimed at the commissioning of the experimental apparatus [3, 4, 5] and confirmation of the predictions for spin-filtering with protons.

In the presentation, a description of the experimental setup and its commissioning phase will be given, together with the results of the measurement.

References

1. PAX Collaboration, spokespersons: P. Lenisa (Ferrara University, Italy) and F. Rathmann (Forschungszentrum Juelich, Germany), <http://www.fz-juelich.de/ikp/pax>.
2. PAX Collaboration CERN-SPSC-2009-012 arXiv:0904.2325, (2009).
3. D. Oellers *et al.*, Phys. Lett. B **674**, 269 (2009).
4. G. Ciullo *et al.*, J. Phys. Conf. Ser. **295**, 012150 (2011).
5. C. Weidemann J. Phys. Conf. Ser. **295**, 012127 (2011).

Recent STAR results on W boson production in polarized $p + p$ collisions at $\sqrt{s} = 500\text{GeV}$

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The production of W^\pm in longitudinally polarized proton+proton collisions is a unique way to study the flavor-dependent spin structure of the proton, since at leading order it couples directly and exclusively to specific quark flavor pairings: $u + \bar{d} \rightarrow W^+$ and $\bar{u} + d \rightarrow W^-$. The STAR experiment measures the spin-dependent production of W^\pm through its $e\nu$ decay channel. Barrel and endcap electromagnetic calorimeters provide measurements of the energy of the electrons and positrons falling within $-1 < \eta < 1$ and $1 < \eta < 2$ respectively, while STAR's large Time Projection Chamber (TPC) provides tracking in $-1 < \eta < 1$ that allows the charge sign of the lepton to be determined. Both the calorimeters and the TPC are used to suppress background through isolation requirements for the candidate track and requirements that energy opposite the candidate in azimuth be consistent with an unseen neutrino. An upgrade to the STAR detector, the Forward GEM Tracker (FGT), is being constructed and installed to extend the pseudorapidity range in which candidate tracks can be reconstructed. Starting in 2009, STAR has collected W candidates from about 100pb^{-1} of proton-proton collisions at $\sqrt{s} = 500\text{GeV}$ with an average polarization of 50%. Results from the original 2009 dataset will be presented, along with prospects for the current dataset, and a discussion of the FGT and its expected impact.

Recent results and future direction of the parity-violating electron scattering program in Hall A at Jefferson Lab

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Hall A at Jefferson Lab has recently completed and published three experiments done using the technique of parity-violating electron scattering. Taken together these experiments are a good demonstration of the versatility of this approach.

HAPPEX detected elastically scattered electrons off a proton target to probe the strange quark form-factor of the nucleon; PREX used elastic scattering off an isotopically pure ^{208}Pb target to measure the neutron skin thickness and thereby constrain the nuclear symmetry energy; while PVDIS used deep-inelastic scattering off Deuterium to measure the axial-vector coupling constants of quarks.

Looking forward, there are two very large scale parity-violation experiments approved to run in Hall A in the 12 GeV era. These experiments represent a significant increase in precision and technical requirements. The MOLLER experiment will measure the weak charge on the electron with the aim of extracting the weak mixing angle with a precision comparable to that achieved by SLD and LEP, which disagree by 3-sigma. The SOLID apparatus will allow ultra precise measurement of deep-inelastic asymmetries over a broad kinematic range, giving a unique sensitivity to Standard Model quark-electron couplings, potential charge symmetry breaking and higher twist effects. Such measurements will probe physics complementary to observations and other direct searches for new particles being made at the LHC.

This presentation will give an overview of the parity-violation program, highlighting the physics results already achieved and making the case for the anticipated future measurements.

Longitudinal Spin Transfer of Λ and $\bar{\Lambda}$ in Polarized Proton-proton Collisions at 200 GeV at STAR

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The longitudinal spin transfer, D_{LL} , of Λ and $\bar{\Lambda}$ hyperons is sensitive to the helicity distribution function of strange quarks and anti-quarks, and to the polarized fragmentation functions. The first proof-of-principle measurement of D_{LL} for inclusive Λ and $\bar{\Lambda}$ hyperons in polarized proton-proton collisions at 200 GeV has been completed at the STAR experiment at RHIC, using a data sample taken in 2005 for an integrated luminosity of 2 pb^{-1} with beam polarization of 50%. A larger data sample corresponding to integrated luminosity of 25 pb^{-1} was collected in 2009 at STAR with beam polarization about 57%, which is expected to improve the D_{LL} precision significantly. The analysis of this data sample is progressing well and its status will be discussed.

Unpolarised Drell-Yan physics at COMPASS-II

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The COMPASS experiment at CERN is a universal facility which can operate with both muon and hadron beams as well as with the longitudinally/transversely polarized solid target. The main goal of the experiment is to study the spin structure of the nucleon. The availability of hadron(pion) beam provides an access to the Drell-Yan physics, i.e. to the process where quark(target)-antiquark(beam) pair annihilates electromagnetically with a production of di-lepton pair. Study of angular dependencies of the Drell-Yan process cross-section allows us to access parton distribution functions (PDFs) or, more precisely, a convolutions of various PDFs.

The COMPASS-II proposal [1], which includes the single-polarized Drell-Yan measurements, was submitted to the CERN SPS committee in May 2010, was recommended by SPSC for approval in September 2010 and approved by CERN research board in December 2010. According to the COMPASS running schedule first polarized DY data taking period will take place in 2014.

In spite of the fact that the main goal of the COMPASS at this stage is a first ever study of the polarized DY reaction, a lot of interesting and important physics can be extracted from the analysis of the spin-averaged (or un-polarised) data. For instance the violation of the important Lam-Tung relation can be studied with much higher statistical accuracy compared to the previous DY experiments, and the flavor dependence of the EMC effect can be determined by performing comparative/combined analysis of the DY pair production on the various targets (NH₃, copper, tungsten). The important contribution of higher twist QCD effect can be studied as well in the azimuthal angular distributions of un-polarised DY (Boer-Mulders function). In this presentation the possible physics subjects to be explored in the un-polarised Drell-Yan experiment at COMPASS will be discussed (complementary measurement with respect to the polarized DY with very minor changes in the set-up) and the sensitivity of measurement will be briefly presented.

References

1. COMPASS Coll., COMPASS-II proposal, CERN-SPSC-2010-014, SPSC-P-340, May 17 2010

Drell-Yan Studies in ppbar Reactions at FAIR

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The nucleonic structure is far to be completely understood. A transverse momentum dependent description of the nucleon structure is a crucial milestone for several forthcoming studies in a wide range of experimental scenarios. By mean of antiproton beams, eventually polarised, that will be available at the future FAIR facility with a beam momentum up to 15 GeV/c, the non-perturbative region of the QCD could be accessed. One of the main goal of the forthcoming experiments at FAIR is the investigation of those Drell-Yan lepton pairs produced in proton-antiproton annihilations, taking advantage of the high expected luminosities.

Drell-Yan studies are a unique tool to access the spin depending properties of the nucleon, and in particular its transverse degrees of freedom. Transverse Momentum Dependent (TMD) Parton Distribution Functions (PDFs), in particular the Boer-Mulders, the Sivers and the Transversity distribution functions, could be widely investigated by mean of the corresponding experimental azimuthal asymmetries. In later stages of FAIR, single- and double-spin asymmetries could be investigated as well. The Drell-Yan physics program which could be accessed at FAIR will be discussed in details, with a particular focus on the PANDA experimental scenario.

Current status of the muon g-2 problem

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Review is given on the current status of experimental and theoretical status of the muon g-2 problem [1]. Prospects of new experiments on more precise measurements of the muon g-2 are briefly discussed. From theoretical side a special attention paid to the problem of calculations of hadronic contributions to the muon g-2. In particular, the light-by-light contribution from the lightest neutral pseudoscalar and scalar mesons to the anomalous magnetic moment of muon is considered in the framework of the nonlocal SU(3) \times SU(3) quark model [2,3]. The model is based on the four-quark interaction of the Nambu–Jona-Lasinio type and Kobayashi–Maskawa–t’Hooft six-quark interaction. Full kinematic dependence of vertices with off-shell mesons and photons in intermediate states in the light-by-light scattering amplitude is taken into account.

References

1. G. W. Bennett *et al.* [Muon G-2 Collaboration], Phys. Rev. D **73** 072003 (2006) [hep-ex/0602035].
2. A. E. Dorokhov, A. E. Radzhabov and A. S. Zhevlakov, Eur. Phys. J. C **71** 1702 (2011) [arXiv:1103.2042 [hep-ph]].
3. A. E. Dorokhov, A. E. Radzhabov and A. S. Zhevlakov, arXiv:1204.3729 [hep-ph].

Spin Physics at ANKE-COSY

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The COSY accelerator and storage ring (Jülich, Germany) provides beams of polarized protons and deuterons in the 0.3–3.7 GeV/c momentum range. The ANKE facility, an internal magnetic spectrometer at COSY, is equipped with polarized hydrogen and deuterium atomic gas targets. These features allow to study various hadronic processes in the intermediate energy range in single and double polarization experiments. The reactions investigated at ANKE include: the **charge-exchange deuteron break-up (CE)** (access to the elementary CE pn scattering amplitudes), the **cumulative mesonless deuteron break-up** (study of short-range NN interactions) and **pion production processes in pp and pn collisions** in the near-threshold region (information on the contact NN π interaction in the Chiral perturbation theory), and in the $\Delta(1232)$ production region (test of existing phenomenological models of NN \rightarrow NN π process). These reactions are considered in a kinematical condition, where “diproton” $\{pp\}_s$, e.g. a proton pair with the low excitation energy, is produced in the final state. The ANKE spectrometer is particularly well-suited for this kinematics. The presence of the tensor polarized deuteron beam lets us investigate the **spin dependence of the $\bar{d}p \rightarrow {}^3He\eta$ excitation function** near the threshold. The future experimental program covers the study of the elementary pp and pn-interaction with polarized beams up to the maximal COSY energy, and a double polarized measurement of the $A_{x,z}$ spin correlation parameter in the $pn \rightarrow \{pp\}_s\pi^-$ process. The latter requires the installation of a Siberian snake at COSY, foreseen in 2013.

In the talk the recent experimental results will be presented and the future measurements will be discussed.

Recent COSY-TOF results on polarization observables in the reaction $\bar{p}p \rightarrow pK^0\Sigma^+$ at $p_{\bar{p}} = 2.95$ GeV/c

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Within the COSY-TOF strangeness physics program the reaction $\bar{p}p \rightarrow pK^0\Sigma^+$ was measured. A 62% polarized proton beam with a momentum of 2.95 GeV/c from the Cooler Synchrotron at the Forschungszentrum Jülich was focused on a liquid hydrogen target. The $pK^0\Sigma^+$ final state was identified based on the analysis of the delayed decays of the strange hadrons $K_s \rightarrow \pi^+\pi^-$ and $\Sigma^+ \rightarrow p\pi^0, n\pi^+$. The azimuthal symmetry and the large acceptance of the detector, as well as the excellent tracking capability allows measuring the complete $pK^0\Sigma^+$ final state distribution.

The polarization of the Σ^+ hyperon is determined and compared with inclusive high-energy experiments. For the first time the analyzing power A_N and the spin transfer coefficient D_{NN} of the Σ^+ hyperon are determined and compared to those of the Λ hyperon.

Polarized Fusion

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The possible gain enhancement in fusion reactors by using polarized fuel has been discussed since more than 50 years, see e.g. [1]. For example, the total cross sections of the fusion reactions $d+t \rightarrow \text{He}^4+n$ or $\text{He}^3+d \rightarrow \text{He}^4+p$ are increased by a factor of about 1.5, if the spins of both incoming particles are aligned. But before polarized fuel can be used for energy productions in the different types of reactors, a number of open questions must be answered. In this talk we give an overview on our various activities in this field of research.

References

1. H. Paetz gen. Schieck, Eur. Phys. J. A 44, 321 (2010).

QCD factorization for structure functions at small x

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We present a new derivation of QCD factorization for DIS structure functions at small x . First, we suggest a new form of the factorization and then reduce it to k_T -factorization. The latter can be reduced to collinear factorization when the unintegrated parton distributions have at least one maximum in k_T . The sharper the maximum is, the more accurate the transition to collinear factorization can be done. Conventionally, fits for parton distributions in both k_T - and collinear factorizations are introduced from purely phenomenological consideration so that any formula for them is acceptable if it matches experimental data. In contrast to this situation we obtain theoretical restrictions on the fits for parton distributions.

Polarized Proton Beam Acceleration at Nuclotron with the use of the Solenoid Siberian Snake

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Abstract

Acceleration of polarized protons in the Nuclotron is analysed. The possibility of the spin preservation during acceleration of the beam up to about 6 GeV with the use of solenoidal "Siberian Snake" placed within the straight section of the accelerator is shown. The options of the "Snake" insertions of 3.2 and 2x3.2 m long were preliminary designed. These are differing of each other by the maximum longitudinal magnetic field of the solenoids. Compensation of the betatron oscillations coupling is provided with the system of quadrupoles turned each around longitudinal axis at some definite angle. The problems of optimal direction of the polarization vector at proton beam injection into the Nuclotron and at the beam extraction from the Nuclotron to the collider NICA and to the main experimental hall as well are discussed.

Does Eta meson have a magnetic moment ?

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Measured magnetic moments of proton, neutron and hyperons can be explained with the assumption that constituent quarks have their own magnetic moments. It is natural to expect for charged spin $\frac{1}{2}$ Dirac particle (quark) to possess a magnetic moment. In the case of mesons, magnetic moments of the constituent anti-quark and quark pair do not necessarily add to zero. Consequently, some mesons can have a magnetic moment. We will concentrate on mesons with zero total spin, containing pairs of quark and anti-quark of identical type (Eta-mesons). In close analogy with positronium (e^+e^-) singlet and triplet bound states [1] it will be shown, that in very strong magnetic fields, Eta-meson quantum state may get mixed with $m_z = 0$ substate of the the corresponding triplet vector-meson (quark - anti-quark) state. The existence of the magnetic moment for such mixed states and the experimental consequences will be discussed. We will also mention the case from nuclear physics, where nuclei with zero total spin and non-zero magnetic moment are expected to exist.

References

[1] A. Rich, Review of Modern Physics 53, p. 127 (1981).

STATUS OF THE SOURCE OF POLARIZED IONS PROJECT FOR THE JINR ACCELERATOR COMPLEX

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The project assumes the design and construction of a universal high-intensity source of polarized deuterons (protons) using a charge-exchange plasma ionizer. The output $\uparrow D^+$ ($\uparrow H^+$) current of the source is expected to be at a level of 10mA. The polarization will be up to 90% of the maximal vector (± 1) for $\uparrow D^+$ ($\uparrow H^+$) and tensor (+1, -2) for $\uparrow D^+$ polarization. Realization of the project is carried out in close cooperation with INR of RAS (Moscow). The equipment available from the CIPIOS ion source (IUCF, Bloomington, USA) is partially used for the Dubna setup also. The new source at the JINR NUCLOTRON accelerator facility will make it possible to increase the polarized deuteron beam intensity up to the level of 10^{10} d/pulse. The first results of a source of polarized atoms testing are presented.

DSMC Simulations of Polarized Atomic Beam Sources Including Magnetic Fields

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In recent decades a lot of work has been done to understand and optimize the output of polarized atomic beam sources. However, there are many effects which prevent a complete analytic description of the system. Now, a DSMC (Direct Simulation Monte Carlo) simulation based on OpenFOAM 1.7.1 using Birds¹ algorithm is set up. So far, the simulated particles have been given spin and a generic utility to include arbitrary magnetic fields has been created. The equation of motion in every timestep is solved by a fourth order Runge-Kutta scheme. First results of the simulations are promising. Additionally a tool to measure the collision age has been created. Further effects to be included are recombination on the walls and spin exchange collisions. After that an algorithm will be included to optimize the output of the atomic beam source.

References

1. G. A. Bird, *Molecular Gas Dynamics and the Direct Simulation of Gas Flows*, Oxford Science Publications, 1998

Measurements of the mid-rapidity parity violating spin asymmetries for W^\pm bosons at PHENIX

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After a first measurement of the $W^\pm \rightarrow e^\pm$ boson spin asymmetry in the 2009 RHIC run in longitudinally polarized p-p collisions at $\sqrt{s}=500$ GeV [1], the PHENIX experiment has collected a total of approximately 46 pb^{-1} in 2011 and 2012, with a consistently higher polarization. With these datasets we expect better constraints on the polarized sea quark distribution functions. The constraints on these polarized distribution functions (PDFs) currently come from DIS experiments alone, which have not reached the accuracy of the valence quark PDFs. PHENIX is able to probe these polarized PDFs through two complementary measurements at forward/backward rapidities with the $W^\pm \rightarrow \mu^\pm$ and at mid-rapidity through the $W^\pm \rightarrow e^\pm$ decay channel. The analysis status and future prospects for the $W^\pm \rightarrow e^\pm$ asymmetry measurement will be presented.

References

1. A. Adare *et al.*, *Phys. Rev. Lett.* **106**, 062001 (2011).

Quark-Antiquark Bound States and QCD Running Coupling within Infrared Confinement

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Bound states of spin-half and spin-one particles are studied within a relativistic quantum-field model based on the infrared confinement. The spectra of quark-antiquark and gluon-gluon states are determined by master equations similar to the ladder Bethe-Salpeter equations. Masses of light, intermediate and heavy mesons are estimated in a wide range of scale (from hundred MeV up to 10 GeV). A new, independent and specific infrared-finite behavior of QCD effective coupling is revealed in the low-energy domain.

References

1. G.Ganbold, Phys. Part. Nucl. **43**, 79 (2012); Part. Nucl. **43**, 156 (2012).
2. G.Ganbold, Phys. Rev. **D81**, 094008 (2010).
3. G.Ganbold, Phys. Rev. **D79**, 034034 (2009).

Status of the polarized ion source at COSY/Jülich

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The COoler SYnchrotron and storage ring COSY at the Forschungszentrum Jülich accelerates protons and deuterons to momenta between 0.6 GeV/c and 3.8 GeV/c [1]. At present beams are used for experiments at several internal and external target places. In addition, polarized proton and deuteron beams are produced and accelerated at COSY routinely. The polarized beams delivered by the colliding beams source [2,3] are preaccelerated in a cyclotron and injected via stripping injection into the COSY ring. The polarization of the circulating beam in COSY is measured continuously during acceleration with the internal EDDA detector [4]. Since January 1996, the cyclotron JULIC operates as the injector of H⁻ or D⁻ beams for the cooler synchrotron COSY at the IKP. Polarized D⁻ ions have been delivered to experiments in sequences of up to fifteen different polarization state combinations. The original source has been designed and set in operation by groups from the universities Bonn, Cologne and Erlangen as a colliding beams source in continuous operation [5]. In parallel to beam delivery to the synchrotron the atomic beam part, the cesium ionizer, neutralizer and the ion extraction have been optimized for pulsed operation. By advancing the components of the polarized ion source the number of polarized particles for injection into the cyclotron has reached about 5×10^{12} protons, delivered in a 20 ms pulse with a repetition rate of 2 seconds [6].

This report describes briefly the characteristics of the ion source in its present mode of operation, the achievements towards higher beam intensities and the efforts to provide polarized H⁻ and D⁻ beams with high reliability.

References

1. R. Maier, Nucl. Instr. Meth. **A 390**, 1, (1997).
2. W. Haeberli, NIM, **62**, 355, (1968).
3. P.D. Eversheim *et al.*, Proc. of Polarized Beams and Polarized Gas Targets, Köln; 224, (1995).
4. V. Schwarz *et al.*, Proc. *SPIN 98*, World Sci., 560, (1998).
5. R. Weidmann *et al.*, *Rev. Sci. Instrum.*, 67 p.II, 1357, (1996).
6. O. Felden *et al.*, Proc. of 11th EPAC, Edinburgh, 1705, (2006).

Singularities in the lepton energy spectrum at ILC for measuring mass and spin of Dark Matter particles

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In many models stability of DM particles D with mass M_D is ensured by the conservation of the new quantum number, called D-parity here. We consider models which contain also charged D-odd particles D^\pm and sometimes another neutral D_A with masses M_+ and M_A respectively. The process $e^+e^- \rightarrow D^+D^-$ with subsequent decay of D^\pm to D plus gauge boson W^\pm (on shell or off shell) was suggested as that for discovery of DM particles in some specific models like MSSM. It has very clear signature and cross section $1 \div 10\%$ from that of total cross section e^+e^- annihilation. The total cross section of process can be determined from the data with reasonable accuracy.

The measuring of edges in the energy distributions of W 's could, in principle, to determine M_D and M_+ . However in the quark decay mode one can determine only upper boundary of energy spectrum. In the lepton decay mode we have incomplete representation of W .

We found that the energy distribution of single lepton (e or μ) from W decay in the process $e^+e^- \rightarrow D^+D^- \rightarrow DDq\bar{q}\ell\nu$ has singular points, independent on properties of D-particles. To determine M_D and M_+ , it is sufficient to measure positions of these singular points in the lepton energy distribution.

With measured values of M_+ the easily calculable in QED cross sections of $e^+e^- \rightarrow D^+D^-$ for spin $1/2$ and 0 differ by a factor ≥ 4 . At $\sqrt{s} > 200$ GeV the model dependent effect of Z exchange can change these values no more than to 20% . The comparison with measured total cross section allows to determine spin of D-particles definitely.

A new forward spectrometer for PHENIX

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In the last decade PHENIX has measured longitudinal gluon polarization inside the proton, probed flavor dependent valence and sea quark helicity distributions and started to explore the proton transverse spin structure.

A major upgrade is planned for the next decade that will provide an increased acceptance and additional tracking and electromagnetic plus hadronic calorimetry in the forward region. This will allow to map out in a wide kinematic range the Sivers effect in Drell-Yan reactions; it will also be possible to access proton transversity and Collins mechanism measuring hadron azimuthal distributions in jets. In addition, with the new forward capabilities we will be able to access proton transversity via its coupling to the universal interference fragmentation function in a collinear framework, without the TMD factorization assumption.

In this talk the layout of the new forward detector system will be discussed, together with the new insights in the proton spin structure that the new forward PHENIX spectrometer will provide.

Flavor dependent azimuthal asymmetries in unpolarized semi-inclusive DIS at HERMES

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The azimuthal $\cos\phi$ and $\cos 2\phi$ modulations of the distribution of hadrons produced in unpolarized semi-inclusive deep-inelastic scattering of electrons and positrons off hydrogen and deuterium targets have been measured in the HERMES experiment.

For the first time these modulations were determined in a four-dimensional kinematic space for positively and negatively charged pions and kaons separately, as well as for unidentified hadrons.

These azimuthal dependences are sensitive to the transverse motion and polarization of the quarks within the nucleon via, e.g., the Cahn, Boer-Mulders and Collins effects.

Spectroscopy of Hadronic Atoms, Heavy Ions, Quarkonia: Spin Effects

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The richness of the spectra of the atomic and hadronic spectra is naturally provided also by the spin-dependent multiplicities. These arise from spin-orbit, tensor, spin-spin interactions between the constituents. Our work is devoted to systematic studying spectra, hyperfine structure of the hadronic (kaonic, pionic) atoms, heavy H-,Li-like ions and quarkonia within ab initio nuclear-relativistic many-body perturbation theory [1] with an accurate account of the relativistic, nuclear, radiative effects. One of the purposes is establishment a quantitative link between quality of nuclear structure modeling and accuracy of calculating spectra. The wave functions zeroth basis is found from the Klein-Gordon-Fock or Dirac-Fock equations for K^+ , π^+ atoms and heavy ions. The potential includes SCF ab initio potential, the electric and polarization potentials of a nucleus (the RMF and Gauss models for a nuclear charge distribution) [1]. The Lamb shift polarization part is treated in the Uhling-Serber approximation and the self-energy part – within the Green function method. For quarkonia the total Dirac Hamiltonian contains a bare Dirac Hamiltonian with adding the quark spin dependent Breit-Fermi operator and spin independent one. We present the accurate data on: 1). Spectra of heavy H-,Li-like ions ($Z= 55-100$); 2). Shifts, widths of low-lying + Rydberg transitions in K^+ , π^+ atoms (H, He,W,Pb,U); as example, see table 1 with data on shifts, induced by strong K-N interaction; 3). The data on spectra for families of charmonium, bottonium, radiative E1 transitions, lepton decay widths in charmonium.

Table 1: Calculated (C) and measured (M) shifts ΔE (keV), induced by strong K-N interaction: a – theory Batty etal; b – our theory (data from [1,2] and refs, therein)

Reference	M		C-a	C-b		
W, 8-7	0.079	0.052	-0.003	0.038		
W, 7-6	-0.353	-0.250	-0.967	-0.294		
Pb, 8-7	0.072	0.047	-0.023	0.046		
U, 8-7	0.12	0.032	-0.405	-0.213	-0.189	-0.205

References

1. A. Glushkov, O. Khetselius, L. Lovett et al, Frontiers in Quant. Syst. in Chem. and Phys., ed. Wilson S., Grout P., Maruani J. et al (Springer) 18,541 (2008); Adv. in Theory of Atom. and Mol. Syst., ed. Piecuch P., Maruani J., Delgado-Barrio G. et al (Springer) 20,125 (2009).
2. C. Batty, M. Eckhause, K. Gall et al, Phys. Rev. C. 40, 2154 (1989); J. Santos, F. Parente, S. Boucard et al, Phys. Rev. A 71, 032501 (2005); K. Seth, Europ. Ph. J. WebC. 3, 07006 (2010)

Muon- γ -Nuclear Spectroscopy: Discharge of Nuclei During μ^- Capture and Spin Effects

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A negative muon μ^- captured by a metastable nucleus may accelerate the discharge of the latter by many orders of magnitude [1]. For a certain relation between the energy range of the nuclear and muonic levels a discharge may be followed by negative muon ejection and μ^- participates in discharge of other nuclei. We present an advanced relativistic energy approach to a discharge of a nucleus with γ quantum emission and further μ^- conversion discharge [2-4]. One should consider 3 channels: i). radiative purely nuclear 2j-poled transition (probability P1; this value can be calculated on the basis of known traditional formula); ii). Non-radiative decay, when a proton transits into the ground state and μ^- leaves a nucleus with energy $E=E(p-N1J1)-E(i)$, where $E(p-N1J1)$ is an energy of nuclear transition, $E(i)$ is the bond energy of μ^- in 1s state (P2); iii). A transition of proton to the ground state with μ^- excitation and emission of γ quantum with energy $E(p-N1J1)-E(nl)$ (P3). As example, data for Sc, Tl nuclei are presented. We use a few approaches to modelling the nuclear system. The first model corresponds to well-known relativistic mean field model, the others models are the Dirac-Wood-Saxon model and Bloumkvist-Wahlborn scheme. As example, below we present some data about the decay probabilities for the Sc nucleus. The probabilities of μ^- -atom decay for some transitions are: i). Bloumkvist-Wahlborn potential: $P_2(p_{1/2}-p_{3/2})=3,93 \cdot 10^{15}$, $P_2(p_{1/2}-f_{7/2})=3,15 \cdot 10^{12}$, $P_2(p_{3/2}-f_{7/2})=8,83 \cdot 10^{14}$; ii). Woods-Saxon potential: $P_2(p_{1/2}-p_{3/2})=3,87 \cdot 10^{15}$, $P_2(p_{1/2}-f_{7/2})=3,09 \cdot 10^{12}$, $P_2(p_{3/2}-f_{7/2})=8,75 \cdot 10^{14}$. If a μ^- -atom is in the initial state $p_{1/2}$, than the cascade discharge occur with ejection of μ^- on first stage and secondly the γ quantum emission. To consider a case when the second channel is closed and the third one is opened, suppose: $E(p_{1/2})-E(p_{3/2})=0,92$ MeV. Energy of nuclear transition is not sufficient to transit μ^- to continuum state and it may excite to 2p state. Then, there is the proton transition $p_{1/2}-p_{3/2}$ with virtual μ^- excitation to states of nd series and γ quantum emission $\hbar\omega=E_p(p_{1/2})+E_\mu(1s)-E_p(p_{3/2})-E_\mu(2p)$. The dipole transition 2p-1s occurs with $P3=1,9 \cdot 10^{13} s^{-1}$ (more than $P(p_{1/2}-p_{3/2})$, $P(p_{1/2}-f_{7/2})$ transitions without radiation.

References

1. V.S. Letokhov, V.I. Gol'danskii, JETP. 67, 513 (1974); L.N. Ivanov, V.S. Letokhov, JETP 70, 19 (1976); A.Glushkov, L.N.Ivanov, Phys.Lett.A 170, 33 (1992); Preprint of ISAN, N-AS1-4, Moscow-Troitsk (1992).
2. A.V.Glushkov, Low Energy Antiproton Phys. (AIP) 796, 206 (2005).
3. A.V. Glushkov, S.V. Malinovskaya, O.Khetselius, Europ.Phys.J. T160, 95 (2008).
4. A.Glushkov, O. Khetselius, A. Svinarenko, Adv. In Theory of Quant. Syst. in Chem. and Phys., ed. Hoggan P., Brandas E., Delgado-Barrio G., Piecuch P. (Springer) 22, 51 (2012)

Polarized and transversity GPDs in kaons leptonproduction

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We analyse the kaon-hyperon channels leptonproduction within the handbag approach where amplitude factorizes into hard subprocess and Generalized Parton Distributions (GPDs).

These reactions are sensitive to the polarized GPDs \tilde{H} and \tilde{E} . It was found that the twist-3 effects are essential in the description of pseudoscalar meson production. Within the handbag approach, these twist-3 effects can be modeled by the transversity GPDs, in particular \tilde{H}_T , \tilde{E}_T , in conjunction with the twist-3 meson wave function. Our results for the cross section and the spin asymmetry for π^0 and η meson production are in agreement with preliminary CLAS data.

In this report we present the model results [1] for the cross section and the spin asymmetry of $K^+\Lambda$, $K^+\Sigma^0$ and $K^0\Sigma^+$ electroproduction. Our predictions for $K^+\Sigma^0$ channel are shown in the Fig.1 as an example.

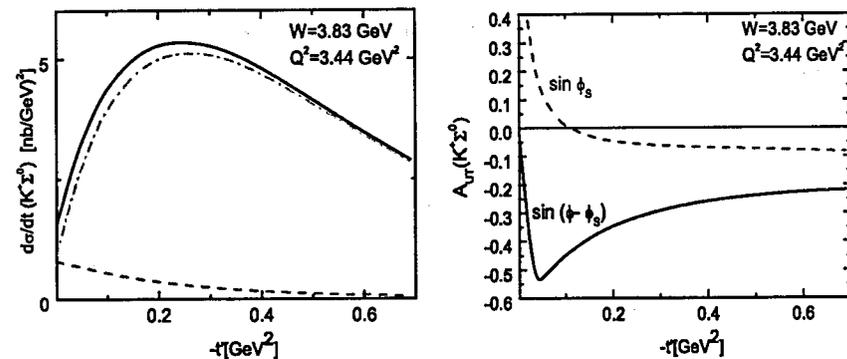


Figure 1: Results for the $K^+\Sigma^0$ electroproduction. (Left): solid (dashed, dashed-dotted) lines represent unseparated (longitudinal, transverse) cross section. (Right): the moments of the transverse target asymmetries in this reaction.

We analyse what observables are sensitive to \tilde{H}_T , \tilde{E}_T GPDs effects.

References

1. S.V. Goloskokov and P. Kroll, Eur. Phys.J. A47, 112 (2011).

Inclusive cross section and single transverse-spin asymmetry of very forward neutron production at PHENIX

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The inclusive cross section and x_F dependence of A_N of very forward neutron production in polarized $p+p$ collisions at $\sqrt{s} = 200$ GeV were measured in the PHENIX experiment at RHIC. We also measured \sqrt{s} and p_T dependence of A_N of very forward neutron production at \sqrt{s} from 62 to 500 GeV. The cross section in large x_F neutron production is explained by one pion exchange model. The observed large asymmetry of neutron production is considered to come from the interference between the spin-flip amplitude of the pion exchange and spin-non-flip amplitude of all Reggeon exchange. Therefore, the neutron asymmetry has a sensitivity to other Reggeon exchange amplitude even if it is a small amplitude.

Muonic hydrogen

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The ($3p - 1s$) X-ray transition to the muonic hydrogen ground state was measured with a high-resolution crystal spectrometer. It supplements studies aiming at an extraction of the isospin separated pion-nucleon scattering lengths from the observation of Lyman transitions feeding the ground state of pionic hydrogen [1].

Muonic hydrogen as a purely electromagnetic twin system to pionic hydrogen offers itself as an ideal candidate for the direct observation of the cascade effects hindering the direct determination of the hadronic broadening in pionic hydrogen [2].

From these measurements, the assumption of a statistical population of the hyperfine levels of the muonic hydrogen ground state was directly confirmed by the experiment and measured values for the hyperfine splitting can be reported [3]. A statistical population of the ground state is an important assumption in the measurement of the induced pseudoscalar coupling in muon capture by the proton [4].

References

1. PSI proposal R-98-01, www2.fz-juelich.de/ikp/exotic-atoms.
2. D. Gotta et al., Lect. Notes Phys. **745**, 165 (2008).
3. D. S. Covita et al., Phys. Rev. Lett. **102**, 023401 (2009).
4. T. Gorringer and H. W. Fearing, Rev. Mod. Phys. **76**, 31 (2004).

Exclusive Study of $d(\bar{e}, e'\bar{p})n$ Reactions at Threshold

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The study of threshold electrodisintegration of and elastic scattering on the only stable two nucleon system, the deuteron, can reveal specific aspects of the nucleon-nucleon interaction. The simplicity of electrodisintegration along with the simplicity of the deuteron makes this study most appropriate for revealing these interactions. By using an incident beam of polarized electrons and by measuring the polarization of the recoiling proton, the ratio of the electric (G_E) and magnetic (G_M) form factors for $d(\bar{e}, e'\bar{p})n$ (and $p(\bar{e}, e'\bar{p})$) reactions may be extracted. This experiment was conducted in Hall A at Jefferson Lab in Newport News, Virginia using a beam of polarized electrons provided by the CEBAF Accelerator incident on a liquid deuterium (and hydrogen) target. The scattered electron and the recoiling (polarized) proton were detected using the High Resolution Spectrometers of Hall A. To determine the polarization of the recoil proton, an analyzing material was placed perpendicular to the protons trajectory through the spectrometer, in front of a set of two straw chambers. Due to the spin-orbit interactions involved in the scattering of the proton from the analyzer material, asymmetries seen in the distribution of events detected by these straw chambers reveal the polarization of the recoil proton. By tracking the spin precession of the polarized protons from the straw chambers back to the target material, the transferred and induced polarization of the proton may be determined. The (single- and double-spin) asymmetries observed in the straw chambers will first be studied for the well-known elastic $p(\bar{e}, e'\bar{p})$ process and compared to the asymmetries for $d(\bar{e}, e'\bar{p})n$ ($x_B=1$). The analysis will then be repeated to determine how these asymmetries change with increasing x_B (to the kinematic limit for deuteron electrodisintegration). This ongoing analysis will be presented and discussed.

Spinpolarised ^3He : From basic research to medical applications

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Polarisation of ^3He by optical pumping is well known since the early 1960s with first applications in fundamental physics. In 1994 it was discovered that one can use hyperpolarised ^3He as contrast agent for magnetic resonance imaging (MRI) of the lung. The wide interest in this new method made it necessary to find ways of polarising ^3He in large quantities and with high polarisation degrees. In addition, storage, transport and administration of hyperpolarised ^3He as well as recovery of this rare helium isotope became important issues in assessing and spreading the new, non-invasive diagnostic tool in research and medical practice.

The talk gives an overview on MRI with hyperpolarised ^3He and shows how fundamental research benefitted from these developments. In particular, the detection of the free precession of co-located $^3\text{He}/^{129}\text{Xe}$ nuclear spins (clock-comparison) will be discussed. This device can be used as ultra-sensitive probe for non-magnetic spin interactions such as the sidereal variation of the $^3\text{He}/^{129}\text{Xe}$ frequency induced by Lorentz-violating couplings. The extreme sensitivity of this "spin-clock" is based on the fact that the oscillator is decoupled from any environmental influences.

How to measure the charm density in the proton

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We study two experimental ways to measure the heavy-quark content of the proton: using the Callan-Gross ratio $R(x, Q^2) = F_L/F_T$ and/or the azimuthal $\cos(2\varphi)$ asymmetry in deep inelastic lepton-nucleon scattering. Our approach is based on the following observations. First, unlike the production cross sections, the ratio $R(x, Q^2) = F_L/F_T$ and the azimuthal $\cos(2\varphi)$ asymmetry in heavy-quark leptonproduction are sufficiently stable, both parametrically and perturbatively, in a wide region of variables x and Q^2 within the fixed-flavor-number scheme of QCD [1,2]. Second, both these quantities, $R(x, Q^2) = F_L/F_T$ and $\cos(2\varphi)$ asymmetry, are sensitive to resummation of the mass logarithms of the type $\alpha_s \ln(Q^2/m^2)$ [3] within the variable-flavor-number schemes [4-6]. This is because, contrary to the transverse structure function $F_T(x, Q^2)$, the longitudinal and azimuth-dependent ones do not contain leading mass logarithms at both leading and next-to-leading orders [7,8]. These two facts together imply that the heavy-quark densities in the nucleon can, in principle, be determined from high- Q^2 data on the Callan-Gross ratio and/or the azimuthal asymmetry in heavy-quark leptonproduction. Our analysis shows that the charm content of the proton can, in particular, be measured using both considered methods in the current COMPASS experiment as well as in future studies at the proposed LHeC [9] and EIC [10] facilities.

References

1. N. Ya. Ivanov, B. A. Kniehl, Eur. Phys. J. C **59**, 647 (2009).
2. N. Ya. Ivanov, Nucl. Phys. B **666**, 88 (2003).
3. T. Stavreva, F. I. Olness, I. Schienbein *et al.*, Phys. Rev. D **85**, 114014 (2012).
4. N. Ya. Ivanov, Nucl. Phys. B **814**, 142 (2009).
5. L. N. Ananikyan, N. Ya. Ivanov, Nucl. Phys. B **762**, 256 (2007).
6. L. N. Ananikyan, N. Ya. Ivanov, Phys. Rev. D **75**, 014010 (2007).
7. E. Laenen, S. Riemersma, J. Smith, and W. L. van Neerven, Nucl. Phys. B **392**, 162 (1993).
8. M. Buza, Y. Matiounine, J. Smith, R. Migneron, and W. L. van Neerven, Nucl. Phys. B **472**, 611 (1996).
9. J. B. Dainton, M. Klein, P. Newman, E. Perez, F. Willeke, J. Inst. **1**, P10001 (2006).
10. A. Deshpande, R. Milner, R. Venugopalan, W. Vogelsang, Ann. Rev. Nucl. Part. Sci. **55**, 165 (2005).

Measurement of spin observables for N^* resonances in pseudoscalar-meson photo-production using polarized neutron in solid HD

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Lattice QCD has recently confirmed the long-standing quark model prediction of many more N^* levels than have been identified to date. However, most resonances overlap due to their large widths and some may not be coupled to the channels that have previously been studied. To explore this issue, the E06-101 experiment has been carried out at CLAS using circularly and linearly polarized photon beams with longitudinally polarized deuterium in the form of solid HD. The experiment ran from December 2011 to May 2012 in Hall-B at Jefferson Lab and is now under analysis. Its goal was to simultaneously measure a complete set of spin observables. While $I = 3/2$ Δ resonances can be determined from proton data alone, $I = N^*$ resonances necessarily require both neutron and proton data. Very little photo-production data exists with neutron targets. The HD solid target was used as a neutron target while proton data were taken at the same time; both H and D in HD target were polarized. Experimental running conditions and preliminary spin asymmetries for pseudo-scalar meson production from polarized neutrons will be discussed. (The companion JLab experiment on the proton, using the FROST target, will be the focus of a presentation by Bill Briscoe at this conference. This talk focuses in detail on the polarized neutron experiment. Details of the polarized HD solid target will be discussed by Xiangdong Wei in a separate presentation.)

Polarization observables in three-nucleon systems

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Three-body systems have been studied in detail at KVI and other laboratories around the world in the last few years. Two categories of reactions have been chosen to investigate these systems, namely elastic and break-up reactions in proton-deuteron scattering in which only hadrons are involved, and proton-deuteron capture reaction involving real and virtual photons in the final state.

Even though a relatively good understanding of most phenomena in nuclear physics at intermediate energies has been arrived at by only considering two-nucleon forces, high precision three-nucleon data have revealed the shortcomings of these forces. Hadronic reactions in three-body systems excluding photons give a handle on effects such as those from three-body forces. In the last few decades, the two-nucleon system has been thoroughly investigated both experimentally and theoretically. These studies have resulted in modern potentials which describe the bulk of the data in a large range of energy. This knowledge can be employed in a Faddeev-like framework to calculate scattering observables in three-body systems. In regions and for the reactions in which the effects of Coulomb force are expected to be small or can be calculated accurately, and energies are low enough to avoid sizable relativistic effects, deviations from experimental data are a signature of three-body force effects.

For the reactions involving a photon, additional effects, such as Meson-Exchange Currents (MEC) have to be taken into account. Calculations show that in the energy range of the present measurements, the three-body force effects are rather small. This offers the possibility, then, to study the MEC effects in the capture reaction.

At KVI, various combinations of high-precision cross sections, analyzing powers and spin-transfer coefficients have been measured at different incident proton or deuteron beam energies between 100 and 200 MeV for a large range of scattering angles and for the reactions mentioned above. Calculations based on two-body forces only do not describe the data sufficiently. The inclusion of three-body forces improves the discrepancies with data significantly. However, there are still clear deficiencies in the calculations. A selection of data for polarization observables will be presented and compared with the state-of-the-art calculations.

Twist-3 quark-gluon correlation contribution to single-transverse spin asymmetry for direct-photon and single-jet productions in pp collision

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We study the single transverse-spin asymmetry A_N for inclusive direct-photon (γ) and single-jet productions in pp collision based on the twist-3 mechanism in the collinear factorization. In this presentation, as a reference for future RHIC experiment, we report our evaluation of A_N by taking into account the whole twist-3 quark-gluon correlation effect inside the transversely polarized proton, based on the formula for A_N derived in [1]. Contributions to the asymmetries arising from the quark-gluon correlation are classified into those from the soft-gluon pole (SGP) and the soft-fermion pole (SFP). The relevant SGP and SFP components of the quark-gluon correlation function have been determined from the RHIC A_N data for the light-hadron productions [2]. In this evaluation we find sizable asymmetries in the forward region of the polarized proton while they are almost zero in the backward region, as seen from Fig.1. We also find in both processes the SFP contribution is vanishingly small in the whole Feynman- x region, suggesting the measurement of these asymmetries provides us with an unique opportunity to determine the net SGP component of the quark-gluon correlation function.

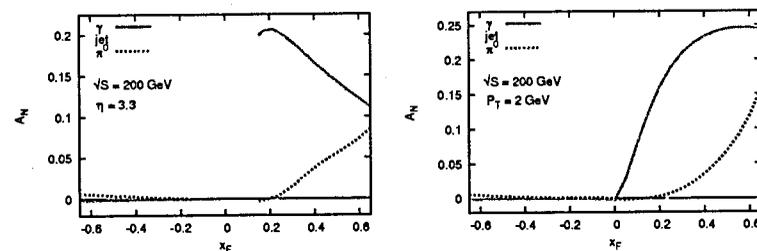


Figure 1: Comparison of A_N for direct-photon, jet and π^0 at fixed pseudorapidity η (left) and transverse momentum P_T (right), respectively. The center-of-mass energy is taken at $\sqrt{S} = 200$ GeV.

References

1. C. Kouvaris *et al.*, Phys. Rev. **D74**, 114013 (2006); Y. Koike and T. Tomita, Phys. Lett. **B675**, 181 (2009); X. Ji *et al.*, Phys. Rev. **D73**, 094017 (2006); K. Kanazawa and Y. Koike, Phys. Lett. **B 701**, 576 (2011).
2. K. Kanazawa and Y. Koike, Phys. Rev. **D82**, 034009 (2010); **D83**, 114024 (2011).

Charged hadron multiplicities at the HERMES experiment

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The HERMES collaboration has measured charge-separated pion and kaon multiplicities in semi-inclusive deep inelastic scattering using a 27.6 GeV electron or positron beam scattering off a hydrogen or deuterium target. The results are presented as functions of the Bjorken variable x , the negative squared four-momentum transfer Q^2 , a hadron fractional energy z and its transverse momentum p_t . These data will be very useful to understand the quark-fragmentation process in deep-inelastic hadron electro-production and will serve as crucial input in the understanding of spin asymmetries in polarized semi-inclusive deep-inelastic scattering.

Scientific program at Nuclotron-NICA

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Accelerator complex: heavy ion collider facility NICA (Nuclotron-based Ion Collider Facility) is under active development at Veksler and Baldin Laboratory of High Energy Physics, JINR (Dubna).

The goal of the project is to study the hot and dense strongly interacting baryonic matter and perform search for possible signs of the mixed phase and critical endpoint in heavy ion collisions (energy $\sqrt{s_{NN}} = 4-11$ GeV for Au⁷⁹⁺ at average luminosity of $L = 10^{27}$ cm⁻² s⁻¹). Another goal of NICA is the spin physics with colliding beams of polarized protons and deuterons. The experiments in Nuclotron extracted beams are considered as well.

Electroweak Interaction and Parity Nonconservation in Heavy Finite Fermi Systems: Spin-Dependent Effects

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During the past decades the nuclear & optical experiments to detect parity nonconservation (PNC) and hyperfine (hf) structure have progressed to the point where PNC amplitudes can be measured with accuracy on the level of a few percents in certain heavy isotopes and significantly worse in some nuclei (Mössbauer spectroscopy) [1-3]. Nowadays the PNC in the finite Fermi-systems has a potential to probe a new physics beyond the Standard Model. We systematically apply our combined nuclear (relativistic mean field approach) and relativistic many-body perturbation theory method [4,5] to precise studying spin-independent and spin-dependent (SD) PNC effect in heavy systems.. There are presented the results of the calculating the nuclear magnetic moments, hf structure, PNC amplitudes for a set of elements: ¹³³Cs, ¹³⁷Ba⁺, ²⁰⁵Tl, ²²³Fr, ²²⁶Ra⁺, ¹⁷³Yb with account of the exchange-correlation, Breit, weak e-e interactions, radiative, nuclear (magnetic moment distribution, finite size, neutron “skin”) corrections. The nuclear SD-PNC interactions due to nuclear anapole moment (k_a contribution), Z- exchange interaction from nucleon axial-vector ($A_n V_e$) currents (k_2), the combined hf and spin-independent Z exchange interaction from nucleon vector ($V_n A_e$) currents (k_{hf}) are studied. As example, in table 1 there are compared the data on different contributions to the SD PNC in ¹³³Cs, obtained by different groups.

Table 1: Theoretical data on SD PNC in ¹³³Cs (in terms of the coefficients k_a , k_2 , k_{hf})

Reference	[1]	[2]	[3]	Our results
Σk_i	0.1169	0.1118	0.112	0.1159
k_2	0.0140	0.0140	0.0111	0.0138
k_{hf}	0.0049	0.0078	0.0071	0.0067
k_a	0.0980	0.090	0.0920	0.0954

References

1. W.R. Johnson, M.S. Safronova, U.I. Safronova, Phys.Rev.A. **67**, 062106 (2003).
2. W.C. Haxton, C.P. Liu, M.J. Ramsey-Musolf, Phys.Rev.C **65**, 045502 (2002).
3. V.V. Flambaum, D.W. Murray, Phys.Rev.C **56**, 1641 (1997).
4. O.Yu. Khetselius, Phys. Scr. **T135**, 014023 (2009) ; Int.J.Quant.Ch.**109**, 3330 (2009).
5. O.Yu. Khetselius, Advances in Theory of Quantum Systems in Chem. and Phys., Ser. Progress in Theor. Chemistry and Physics, eds. K. Nishikawa, J. Maruani, E. Brandas et al (Springer) **57** (2012).

Blood analysis for early cancer detection

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Abstract

A promising way for early cancer detection without any exposure to radiation of a patient is introduced. The method is based on isotopic analysis and the measurement of average values of electric field gradients on the quadrupolar nuclear spins in a blood sample of about 3-4 cm³. Both isotopic and gradient measurements are not accessible through traditional chemical analyses. The method requires:

- Cooling down a blood sample at nitrogen temperature to freeze molecular movements.
- Beam irradiation of the cooled sample to induce hyperfine interactions between quadrupolar nuclear and the proton spins.
- Dynamic Nuclear Polarization of spins at about 0.2 K in the magnetic field.
- The study of NMR-line shape asymmetries by decoupling isotopes from proton spins.
- Correlation of cancer evolution with asymmetry of proton spectra.

Preliminary tests with irradiated ammonia (NH₃) in Compass experiment at CERN [1, 2] showed this study as a perspective way to understand if some anomalous in the two new parameters point out the early cancer symptoms.

References

1. Yu.F. Kiselev and S.I. Tiutiunnikov, Spin-Isotopic analysis at superlow temperatures, Proceedings of XIII Advanced Res. Workshop on HESPh (DSPIN-09), 2009, 401.
2. Yu. Kiselev (On behalf of the COMPASS collaboration at CERN), Blood sample analysis for early cancer diagnostic, Abstract188, Geneva, Int. Conf. on Translat. Res. in Rad. Oncology, ICTR-PHE 2012 (February 27-March 2, 2012).

Two photon exchange correction at large momentum transfer within QCD factorization approach

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Precision measurements of the proton electric to magnetic form factor ratio at larger Q^2 using polarization experiments [1] have revealed significant discrepancies in recent years with unpolarized experiments using the Rosenbluth technique [2]. As no experimental flaw in either technique has been found, two-photon (2γ) exchange processes, see Fig.1, are the most likely culprit to explain this difference. Their study has received a lot of attention past decade.

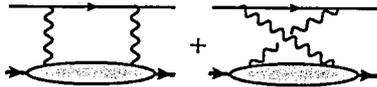


Figure 1: Two photon exchange correction to elastic ep -scattering

Calculation of the TPE diagrams in Fig.1 in the region with large Q in QCD is a difficult task. The first step in this direction has been made in [3] where the classical hard spectator scattering mechanism was considered in order to establish the power of $1/Q$ in the asymptotic of TPE amplitudes. But numerical estimates demonstrate that this contribution can not resolve the discrepancy between the polarized and unpolarized data. There are arguments that substantial numerical contribution can be provided by the so-called soft-overlap contribution (=soft spectator scattering). In our presentation we suggest the complete factorization formula describing the leading in $1/Q$ behavior of the elastic ep scattering amplitude with hard 2γ exchange. In our approach we consider both the hard and soft spectator contributions. Using obtained results we carried out the phenomenological analysis of existing data: reduced cross section measured in [2] and polarization observables measured in [1] and made predictions for the ratio $\sigma^{e^+p}/\sigma^{e^-p}$ which will be measured in the several ongoing experiments.

References

1. M.K.Jones *et al.*, Phys.Rev.Lett.**84**, 1398 (2000); V.Punjabi *et al.*, Phys.Rev.C **71**, 055202 (2005); O.Gayou *et al.*, Phys.Rev.Lett.**88**, 092301 (2002); A.J.R.Puckett, *et al.*, Phys.Rev.Lett.**104** 242301 (2010); M.Meziane *et al.*, Phys.Rev.Lett.**106** 132501 (2011);
2. L.Andivahis *et al.*, Phys.Rev.D **50**, 5491 (1994); M.E.Christy *et al.*, Phys.Rev.C **70**, 015206 (2004); I.A.Qattan *et al.*, Phys.Rev.Lett. **94**, 142301 (2005).
3. D.Borisjuk and A.Kobushkin, Phys.Rev.D **79**, 034001 (2009); N.Kivel and M.Vanderhaeghen, Phys.Rev.Lett. **103**, 092004 (2009).

The decays of polarized gauge bosons into quark pairs at NLO QCD

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The polarization of W^\pm and Z bosons produced in electroweak production processes is in general highly nontrivial. One therefore has a rich phenomenology of polarization effects in W^\pm, Z production and decay which will be explored in present and future high energy experiments. The polarization of the W^\pm and Z bosons can be probed by decay correlations involving the decay products of the polarized (W^\pm, Z) bosons. A widely discussed prominent example of such decay correlations is the decay $t \rightarrow b + W^+$ followed by $W^+ \rightarrow \ell^+ \nu_\ell$ where the decay $W^+ \rightarrow \ell^+ \nu_\ell$ is used to analyze the helicity fractions of the W^+ resulting from the decay process $t \rightarrow b + W^+$ (see e.g. Refs. [1,2]).

We explore the possibility to also make use of the quark-antiquark decay modes $W^\pm \rightarrow q_1 \bar{q}_2$ and $Z \rightarrow q \bar{q}$ to analyze the polarization of the gauge bosons, in particular using the tagging modes $W^+ \rightarrow c \bar{b}, c \bar{s}$ and $Z \rightarrow c \bar{c}, b \bar{b}$ involving heavy quarks. One therefore needs to calculate the polarized decay structure functions in the decay of polarized W^\pm, Z gauge bosons into massless and massive quark-antiquark pairs which we do at NLO QCD. We find a surprisingly strong dependence of the polarized decay structure functions on finite quark mass effects at NLO even at the relatively large mass scale of the W^\pm and Z bosons.

References

1. T. Aaltonen *et al.* [CDF and D0 Collaborations], "Combination of CDF and D0 measurements of the W boson helicity in top quark decays", arXiv:1202.5272 [hep-ex]
2. Y. Peters [D0 and CDF and Atlas and CMS Collaborations], "Top Quark Properties," arXiv:1112.0451 [hep-ex]

Preservation And Control Of The Proton And Deuteron Polarizations In The Proposed Electron-Ion Collider At Jefferson Lab

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We propose a scheme of preserving the proton and deuteron beam polarizations during acceleration and storage in the proposed electron-ion collider at Jefferson Lab. This scheme allows one to provide both the longitudinal and transverse polarization orientations of the proton and deuteron beams at the interaction points of the figure-8 ion collider ring. We discuss questions of matching the polarization direction at all stages of the beam transport including linac, pre-booster, large booster and ion collider ring.

Measurement of Semi-Inclusive Double-Spin Asymmetries and the Spin-Structure Function g_2 at HERMES

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Preliminary results on the semi-inclusive double-spin asymmetries measured at HERMES with a longitudinally polarized hydrogen and deuterium targets are presented. The kinematic dependencies of the asymmetries on x_B , the hadron energy fraction z and hadrons transverse momentum $p_{h\perp}$ are explored. Final results on the measurement of the spin-structure function g_2 and the virtual-photon asymmetry A_2 are presented. The Burkhardt-Cottingham integral for the measured region of x and the twist-3 matrix element d_2 are evaluated.

Transverse Single Spin Asymmetries in polarized proton-proton Collisions at PHENIX

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Polarized proton-proton collisions are a powerful tool to study the transverse spin structure of the proton. This talk will discuss the RHIC/PHENIX single transverse spin asymmetries, which is a simple left-right asymmetry in hadron production from the collision between a polarized proton beam and an unpolarized proton target. In particular, spin asymmetry measurements performed at forward rapidity probe proton structure in previously unexplored kinematic regimes. The measurements are done at high transverse momentum, where perturbative QCD is expected to describe the hadron production. The asymmetries are sensitive to a mixture of effects: the Sivers and Collins effects which introduce transverse momentum dependent effects in the proton and in the fragmentation process, respectively; and higher-twist effects.

Measurements at forward, mid and backward rapidity will be shown from datasets collected at center of mass energies of 62 and 200 GeV. In addition, the near-term outlook using a high luminosity, high polarization dataset taken in the spring of 2012 will be presented.

QCD analysis of the Bjorken sum rule

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Following the recent papers [1-3], the polarized Bjorken sum rule is studied at low momentum transfers in the framework of the QCD perturbation theory as well as standard and with frozen and analytic versions of the coupling constant. A good agreement between experimental data and the theoretical predictions is found. As in earlier studies [4-6], the results of the use of frozen and analysis of the coupling constants are close to each other.

References

1. R.S. Pasechnik, D.V. Shirkov and O.V. Teryaev, Phys. Rev. D **78**, 071902 (2008).
2. R.S. Pasechnik, D.V. Shirkov, O.V. Teryaev, O.P. Solovtsova and V.L. Khandramai, Phys. Rev. D **81**, 016010 (2010).
3. V.L. Khandramai, R.S. Pasechnik, D.V. Shirkov, O.P. Solovtsova and O.V. Teryaev, Phys. Lett. B **706**, 340 (2012).
4. A.V. Kotikov, A.V. Lipatov and N.P. Zotov, J. Exp. Theor. Phys. **101**, 811 (2005) [Zh. Eksp. Teor. Fiz. **128**, 938 (2005)].
5. G. Cvetic, A.Y. Illarionov, B.A. Kniehl and A.V. Kotikov, Phys. Lett. B **679**, 350 (2009).
6. A.V. Kotikov, V.G. Krivokhizhin and B.G. Shaikhatdenov, Phys. Atom. Nucl. **75**, 507 (2012).

Polarized Deuterons and Protons at NICA@JINR

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Abstract

The planned operation modes of the NICA include polarized protons and polarized deuteron collisions at maximum c.m. energy up to $\sqrt{s} \sim 26$ GeV and $\sqrt{s_{NN}} \sim 12.5$ GeV respectively. The average luminosity of $L \sim 1 \cdot 10^{31}$ cm⁻² s⁻¹ is expected [1,2]. Moreover, different spin directions should be provided for both proton and deuteron beams. The problems of reaching the mentioned parameters were analysed and the new solutions have been found. The proposed scheme provides longitudinal and transverse polarization as well in the two beam intersection points (IP) of the collider and in the both cases, i.e. of the proton or deuteron collisions. The new scheme can work in two regimes, namely: with the use of one or two solenoidal "Siberian Snakes". The use of only one "snake" exclude crossing of spin resonances during the beam acceleration process, whereas adding the second "snake" make it possible to shift the beam to the spin resonance. One has the unique possibility to obtain different directions of the particle spin in the both IP's by means of additional insertions with low values of magnetic field integrals for different particles, including deuterons.

Violent Collisions of Spinning Protons:

Past, Present & Perhaps at Fermilab

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First will be a review the history of elastic scattering and polarized proton beams, and the unexpected and still unexplained large transverse spin effects found in high energy proton-proton spin experiments at the ZGS, CERN, AGS, Fermilab and RHIC. Next, will be a discussion of possible transverse spin experiments on violent elastic and inclusive collisions of polarized protons at Fermilab's new high-intensity Main Injector.

Determination and applications of generalized parton distributions

P. Kroll (*Universität Wuppertal*)

A survey will be given on an extensive analysis of exclusive electroproduction of light mesons at small Bjorken- x within the handbag approach. The contributing GPDs are constructed by means of double distributions. Constraints from parton distributions, sum rules and positivity bounds are taken into account and the remaining free parameters of the double distributions are fitted to experiment. What has been learned about the GPDs from this analysis will be summarized and various applications will be presented as for instance the evaluation of Ji's sum rule or the transverse localization of partons. From the analysis it turned out that the contributions from the asymptotically dominant longitudinally polarized photons do not suffice to describe experiment. Transversally polarized photons also play an important role. Within the handbag approach these contributions are to be modelled by transversity (helicity flip) GPDs and twist-3 meson wave functions. The set of extracted GPDs can also be used for a parameter-free calculation of DVCS. It will be shown that very good agreement with all available DVCS data is obtained. Finally, it will be commented on applications of the GPDs to exclusive electroproduction of mesons and photons at Jlab kinematics which is characterized by large values of Bjorken- x and small values of W .

Deuteron beam polarimetry at Nuclotron

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The scheme of the deuteron beam polarization measurements at Nuclotron are presented. A deuteron beam polarimeter based on the spin-asymmetry measurements in the dp - elastic scattering at large angles in center-of-mass system has been constructed at the Internal Target Station at the Nuclotron of JINR. This polarimeter is planned to use for the measurements of the vector and tensor components of deuteron beam polarizations at the energies 270-2000 MeV simultaneously.

Some details on the low energy and extracted beams polarimeters are also discussed.

Synthesis and Labeling of Tc-DISIDA
(N-2,6-diisopropyl-phenylcarbamoylmethlyiminodiacetic acid)

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Radiopharmaceuticals are compounds labeled with a radioactive isotope that are used for studying different organs in the human body. Technetium-99m labeled iminodiacetic acid (IDA) derivatives are commonly used as hepatobiliary imaging agents. Radiopharmaceutical use for hepatobiliary imaging are divided into two groups based on the physiologic function of the liver they are designed to evaluate. The IDA agent of choice for NECSA(NTP) is DISIDA. A cold kit is a pre prepared vial consisting of the compound to be labeled with the radioactive isotope and a suitable reducing agent. Twenty gram of DISIDA is needed for each production batch of DISIDA kits labeling is accomplished by adding 99m-TcO₄ to the kit and mixing well. Approximately 3-5 mCi (111-185MBq)99mTc-IDA derivative is injected intravenously into patients who have fasted for 4-6 hours prior to administration. The biodistribution DISIDA was confirmed by performing a biodistribution study on a Chacma baboon. The yield with technetium give > 95% radiochemical purity. The improved synthesis resulted in increased cost effectiveness of the commercial DISIDA kits.

Spin physics in few body systems at Nuclotron

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The review of the recent results on spin effects in few nucleon systems obtained at LHEP-JINR are presented. The data on the deuteron analyzing powers in different reactions in the wide energy range demonstrate the sensitivity to the spin structure of the light nuclei. The future plans on the studies with polarized deuterons from new polarized ion source at Nuclotron will be reported.

Spin effects in the $dd \rightarrow {}^3\text{He} n$ reaction at intermediate energies

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The $dd \rightarrow {}^3\text{He} n$ reaction is considered at the energies between 200 MeV and 520 MeV. The calculations are performed within relativistic multiple scattering model based on the Alt-Grassberger-Sandhas equations. The angular dependences of the differential cross section and vector and tensor analyzing powers are given in comparison with the experimental data.

Prompt Photon A_N with the PHENIX MPC-EX Detector

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The PHENIX MPC-EX detector is a Si-W preshower extension to the existing Muon Piston Calorimeter (MPC). The MPC-EX will consist of eight layers of alternating W absorber and Si mini-pad sensors and will be installed in time for RHIC Run-15. Covering a large pseudorapidity range, $3.1 < |\eta| < 3.8$, the MPC-EX and MPC access high- x partons in the projectile nucleon (and low- x partons in the target nucleon) in transversely polarized proton-proton collisions at 200 GeV. With the addition of the MPC-EX, the neutral pion reconstruction range extends to energies > 80 GeV, a factor of four improvement over current capabilities. Not only will the MPC-EX strengthen PHENIX's existing forward π^0 and jet measurements, it also provides the necessary π^0 rejection to make a prompt photon measurement feasible. With this π^0 rejection, prompt photon yields at high p_T , $p_T > 3$ GeV, can be statistically extracted using a double ratio method. This will make possible a measurement of the prompt photon single spin asymmetry A_N in transversely polarized p+p collisions, and will help elucidate the correlation of valence partons in the proton with the proton spin.

Results of Searches for Higgs Boson and New Physics at LHC

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I will present an overview of the recent results from the LHC experiments. Emphasis is on the searches for Higgs Boson and New Physics from the 7 and 8 TeV data, addressing also separation of spin hypotheses of a Higgs-like resonance based on Monte Carlo studies. Quarkonia polarization measurements at 7 TeV data are presented.

References

1. CMS Collaboration, CMS Physics Results, <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults>
2. ATLAS Collaboration, ATLAS Physics Results, <https://twiki.cern.ch/twiki/bin/view/AtlasPublic>
3. ALICE Collaboration, ALICE Publications, <http://aliceinfo.cern.ch/ArtSubmission/>

Qweak, $N \rightarrow \Delta$, and Physics Beyond the Standard Model

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The Qweak experiment recently finished the data-taking phase at the Thomas Jefferson National Accelerator Facility. Qweak aims to measure the weak charge of the proton, Q_W^p , via parity-violating elastic electron-proton scattering. The expected value of Q_W^p is fortuitously suppressed which leads to an increased sensitivity to physics beyond the Standard Model.

The experimentally measured value is the asymmetry between left- and right-handed electron-proton interactions and is given in Equation 1,

$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}, \quad (1)$$

where A is the asymmetry and $\sigma_{R,L}$ is the cross-section for right- or left-handed electron interactions. The weak interaction is accessible because of the interference of the electromagnetic and weak interactions. The interference term carries the sign of the handedness of the electrons and results in magnification of the observable weak interaction strength given in Equation 2.

$$A \approx \frac{\mathcal{M}_Z}{\mathcal{M}_\gamma} \approx -200 \text{ ppb} \quad (2)$$

The high-quality, highly polarized electron source at Jefferson Lab permits a measurement of Q_W^p to high precision. Because of the quality of the beam, high currents of 180 μA can be used to reach an event rate of ~ 7 GHz, dramatically reducing the amount of time needed to make this measurement.

The suppression of Q_W^p in the Standard Model and proposed precision of the measurement allow for a ~ 2 TeV search of new parity-violating physics. An overview of Qweak, an update on the data-analysis, ancillary measurements, and the reach for new physics will be presented.

On the controversy concerning the definition of quark and gluon angular momentum

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One of the key questions in understanding the internal structure of the nucleon in QCD is how the momentum and angular momentum of a nucleon is built up from the momenta and angular momenta of its constituents. A major controversy has arisen as to how to split the total angular momentum into separate quark and gluon contributions, and as to whether the gluon angular momentum can itself be split, in a gauge-invariant way, into a spin and orbital part. It has long been believed that such a splitting cannot be done in a gauge-invariant way, but several authors have claimed that it is possible to do this and that even in QED the traditional, decades-old textbook method of identifying electron and photon angular momentum is incorrect! I shall give a pedagogical introduction to the subject and then assess the various claims in the literature.

Measurement of A_{LL} and cross section of high p_T charged π meson production for constraining ΔG at PHENIX

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Precision measurements via various single inclusive and less inclusive channels remain a crucial program at PHENIX in order to constrain polarized gluon contribution ΔG and disentangle the proton angular momentum composition. Global analysis^[1] with the inclusion of neutral pion double longitudinal asymmetry A_{LL} measurements in the past was able to hint at not sizable contribution from gluon polarization. Due to the complexity of global analysis, however, independent measurements through different final state particle productions are inevitable to be able to draw any conclusion.

A large set of data with integrated luminosity of 16 pb^{-1} was recorded from p-p collisions in 2009 and were analyzed for charged π meson production at mid-rapidity $\sqrt{s} = 200 \text{ GeV}$. Compared with the analysis that involved only central arm detectors, there has been significant improvement on A_{LL} and cross section measurements in reducing background level from as high as 20% down to <2% as a result of including the Hadron Blind Detector^[2] in the analysis.

High p_T ($5 < p_T < 12 \text{ GeV}/c$) charged π production covers the kinematic range of $.10 < \langle x \rangle < .15$ and $Q^2 > 10 \text{ GeV}^2$. Being safely in the perturbative regime and the availability of polarized Parton Distribution Functions, Fragmentation Functions^[3] and perturbative QCD hard scattering cross section at NLO, combined with much improved purity of measurement, renders the charged π venue more robust and readily usable for global analysis. This talk will present the status on A_{LL} , cross section measurements and global analysis.

References

1. D. de Florian, R. Sassot, M. Stratmann and W Vogelsang, Phys. Rev. D **80**, 034030 (2009).
2. W. Anderson *et al.*, Nucl. Instr. and Meth. in Phys. Res. A **646**, 35-58 (2011).
3. D. de Florian, R. Sassot, M. Stratmann, Phys. Rev. D **75**, 114010 (2007).

Twist-3 contributions to the azimuthal asymmetries in polarized SIDIS

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We extend the collinear expansion to the semi-inclusive deep inelastic lepton nucleon scattering process $l+N \rightarrow l+q+X$. We calculate the contributions up to twist 3 in different polarized cases. We present the results obtained and discuss the implications for future experiments.

References

1. Zuo-tang Liang and Xin-Nian Wang, *Phys. Rev.* **D75**, 094002 (2007).
2. Yu-kun Song, Jian-huaGao, Zuo-tang Liang and Xin-Nian Wang, *Phys. Rev.* **D83**, 054010 (2011).
3. Yu-kun Song, Jian-huaGao, Zuo-tang Liang and Xin-Nian Wang, (2012) in preparation.

Hadron Polarization Phenomena in the TeV Regime

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Obtaining a coherent picture of Single Spin Asymmetries (SSAs) in hard processes has been a long standing question in QCD. A particularly puzzling phenomenon, which yet needs to be explained and which seems to persist in preliminary LHC measurements, is the inclusive production of polarized Λ 's from unpolarized protons. Experiments show large transverse polarizations, contradicting the expectation from Perturbative QCD that polarization should be small as proportional to both α_s and the struck quark mass. In this talk we present a possible mechanism to interpret inclusive Λ production based on the observations that: 1. A large SSA can be generated only by introducing a phase difference at the amplitude level; 2. A Generalized Parton Distributions (GPDs) formalism provides the theoretical tool to realize such a condition at leading twist.

On the Interpretation of Recent Exclusive Pseudoscalar Electroproduction Results

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Exclusive pseudoscalar meson electroproduction from nucleons was recently suggested for extracting the tensor charge and other quantities related to transversity from experimental data, the helicity structure for this C-odd process being described by the quark helicity flip, or chiral-odd Generalized Parton Distributions (GPDs). Model calculations indicate how various transversity parameters can be related to cross section and spin asymmetry measurements over a broad range of kinematics. In this presentation we will discuss in detail:

- i) the connection between the helicity description and the cartesian basis;
- ii) the dependence on the momentum transfer squared, Q^2 ;
- iii) the angular momentum, parity, and charge conjugation constraints (J^{PC} quantum numbers).

Angular momentum sum rule for spin one hadronic systems

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We will present a sum rule for the total quark angular momentum of a spin-one hadronic system within a gauge invariant decomposition of the hadron's spin. We will show various phenomenological implications, including a connection to the structure function b_1 , and to deeply virtual Compton scattering experiments using transversely polarized deuterons.

Chiral-odd transverse momentum distributions in Drell-Yan processes

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We study the azimuthal asymmetries in proton-proton Drell-Yan processes, as well as pion-nucleon Drell-Yan processes, with one incident nucleon being transversely or longitudinally polarized. We consider particularly the asymmetries contributed by the leading-twist chiral-odd quark distributions, including the Boer-Mulders function, the transversity, the pretzelosity and h_{1L}^{\perp} . We analyze the asymmetries [1] with $\sin(2\phi+\phi_S)$ and $\sin(2\phi-\phi_S)$ modulations in transversely polarized $p^\uparrow p$ Drell-Yan and the $\sin 2\phi$ asymmetries in longitudinally polarized $p^\rightarrow p$ Drell-Yan at RHIC, J-PARC, E906 (Fermi Lab) and NICA (JINR), respectively. We also predict the same azimuthal asymmetries in pion-nucleon Drell-Yan processes at COMPASS [2,3]. We show that the measurements on the asymmetries in those facilities can provide valuable information of the chiral-odd structure of the nucleon in the valence and sea regions, as well as the Boer-Mulders function of the pion.

References

1. Z. Lu, B.-Q. Ma and J. Zhu, Phys. Rev. D **84**, 074036 (2011).
2. Z. Lu, B.-Q. Ma and J. She, Phys. Rev. D **84**, 034010 (2011).
3. Z. Lu, B.-Q. Ma and J. She, Phys. Lett. B **696**, 513 (2011).

Entangled Quantum States and Correlations of Internal Quantum Numbers in Two-Particle Systems

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The properties of nonfactorizable (entangled) two-particle quantum states are discussed . The study of spin correlations of two identical particles with spin 1/2 at low relative momenta is performed. The angular correlations of decay directions for two unstable particles, connected with the correlations of their spin quantum numbers, are considered. It is shown that, for nonfactorizable two-particle states, the "classical" incoherence inequalities for the correlation tensor components [1], being analogous to the Bell inequalities, may be violated . Concretely, the spin correlations and angular correlations for the systems $(\mu^+\mu^-)$, $(\tau^+\tau^-)$, produced in the reactions $e^+e^- \rightarrow \mu^+\mu^-$, $e^+e^- \rightarrow \tau^+\tau^-$ [2], for the systems of final leptons in the processes $\gamma\gamma \rightarrow e^+e^-$, $\mu^+\mu^-$, $\tau^+\tau^-$ [3], and also for the $\Lambda\Lambda$ and $\bar{\Lambda}\bar{\Lambda}$ systems generated in relativistic heavy-ion collisions [4], have been analyzed . It is noted that the sharp change of the correlation tensor for the $\bar{\Lambda}\Lambda$ pair with the increase of energy may testify to the passage through the "mixed phase" [4].

Some other correlations of internal quantum numbers, being analogous in structure and having the strongly pronounced quantum character, have been also considered : spin correlations in the $(p, {}^3He)$ system formed in the reaction $\pi^+ + {}^4He \rightarrow p + {}^3He$ [5], correlations of linear and circular polarizations of two γ quanta [6], and correlations at the registration of two neutral K mesons generated in inclusive multiparticle processes with the strangeness conservation [7] (and also pairs of neutral charmed and beauty mesons $D^0\bar{D}^0$, $B^0\bar{B}^0$, $B_s^0\bar{B}_s^0$ [8]).

References

1. R. Lednicky and V.L. Lyuboshitz, Phys. Lett. **B508**, 146 (2001).
2. V.L. Lyuboshitz and V.V. Lyuboshitz, Yad. Fiz. **72**, 340 (2009) [Phys. At. Nucl. **72**, 311 (2009)] .
3. V.L. Lyuboshitz and V.V. Lyuboshitz, Proc. of the DSPIN-09 Workshop (JINR E1,2-2010-13, Dubna, 2010), p. 91.
4. V.L. Lyuboshitz and V.V. Lyuboshitz, Yad. Fiz. **73**, 836 (2010) [Phys. At. Nucl. **73**, 805 (2010)] .
5. V.L. Lyuboshitz and V.V. Lyuboshitz, Yad. Fiz. **63**, 837 (2000) [Phys. At. Nucl. **63**, 767 (2000)] .
6. V.L. Lyuboshitz and V.V. Lyuboshitz, EChAYa, **36** (No. 7B), 123 (2005) [Phys. Part. Nucl. **36** (Suppl. 2), p. S198 (2005)] .
7. V.L. Lyuboshitz and V.V. Lyuboshitz, Pis'ma v EChAYa , **4** , 654 (2007) [Phys. Part. Nucl. Lett., **4**, 388 (2007)] .
8. V.L. Lyuboshitz and V.V. Lyuboshitz, Proc. of the Helmholtz Int. School "Heavy Quarks 2008" (DESY-PROC-2009-07, Hamburg, 2009), p. 299 .

Quark Transversal Motions in the Proton Spin Issues

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The transversal motions of quarks play a significant role in various physical quantities related to the proton spin structure, such as the helicity and transversity distributions, and the transverse-momentum-dependent (TMD) or three-dimensional parton distributions (3dPDFs). It is shown that the relativistic effect due to quark transversal motions plays a model-independent role to understand the proton spin puzzle: why the quark helicity sum does not equal to the proton spin. I also show that the quark transversal motions are important in the investigations of TMDs or 3dPDFs for theoretical predictions that can be checked in various experimental processes.

This talk is based mainly on following References:

- 1 X. Zhang and B.-Q. Ma, Phys. Rev. D **85**, 114048 (2012) [arXiv:1206.0808 [hep-ph]].
- 2 J. Zhu and B.-Q. Ma, Phys. Lett. B **696**, 246 (2011) [arXiv:1104.4564 [hep-ph]].
- 3 J. She, J. Zhu and B.-Q. Ma, Phys. Rev. D **79**, 054008 (2009) [arXiv:0902.3718 [hep-ph]].
- 4 S. J. Brodsky, D. S. Hwang, B.-Q. Ma and I. Schmidt, Nucl. Phys. B **593**, 311 (2001) [hep-th/0003082].
- 5 B.-Q. Ma, I. Schmidt and J. Soffer, Phys. Lett. B **441**, 461 (1998) [hep-ph/9710247].
- 6 B.-Q. Ma, Phys. Lett. B **375**, 320 (1996) [hep-ph/9604423].
- 7 B.-Q. Ma and Q.-R. Zhang, Z. Phys. C **58**, 479 (1993) [arXiv:hep-ph/9306241].
- 8 B.-Q. Ma, J. Phys. G **17**, L53 (1991) [arXiv:0711.2335 [hep-ph]].

Analytic determination of the electromagnetic moments and form-factors of the Δ resonances and deuteron in the $\pi N - \gamma\pi N$ and $NN - \gamma NN$ reactions

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The πN and NN bremsstrahlung $\pi N \Rightarrow \gamma\pi'N'$ and $NN \Rightarrow \gamma'N'N'$ are studied within current conservation which is present in form of Ward-Takahashi identities for the on shell amplitudes. According to these identities the on shell internal particle radiation amplitude and the corresponding part of the on shell external particle radiation amplitude cancel each other. In particular, it is shown that the double Δ exchange diagram with the vertex $\Delta - \gamma'\Delta'$ compensate the appropriate part of the external particle radiation diagrams. Similarly, the double deuteron exchange diagram with the vertex $d - \gamma'd'$ cancel the corresponding part of the external nucleon radiation diagrams. This cancellation determines the $\Delta - \gamma\Delta$ and $d - \gamma d$ form factors through the wave functions $\Delta - \pi N$ and $d - NN$. Consequently, the model independent analytic relation between the magnetic dipole moments of the Δ 's and the full magnetic moment of the proton μ_p and neutron μ_n are obtained, i.e. $\mu_{\Delta^+} = \frac{M_{\Delta}}{m_p}\mu_p$, $\mu_{\Delta^{++}} = \frac{3}{2}\mu_{\Delta^+}$, $\mu_{\Delta^0} = \frac{M_{\Delta}}{m_n}\mu_n$ and $\mu_{\Delta^-} = \frac{3}{2}\mu_{\Delta^0}$. Similarly, it is demonstrated that the S -wave part of the dipole magnetic moment of the deuteron is $\mu_d^S = \mu_p + \mu_n$.

We have shown that the suggested current conservation for the on mass shell amplitudes and the following cancellation of the internal and external particle radiation diagrams are the same in the quantum field theories with and without quark-gluon degrees of freedom. Therefore, the present analytical results are valid also in the framework of the theory with the quark-gluon degrees of freedom.

References

1. A. I. Machavariani and A. Faessler. Journal of Phys. G. **37**, 075004 (2010).
2. A. I. Machavariani and A. Faessler. Journal of Phys. G. **38**, 035002 (2011).

Thoughts on Polarimetry for High Energy Polarized ^3He beams at RHIC

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With the advent of polarized ^3He beams for RHIC, I will present some ideas for polarimetry utilizing the Coulomb Nuclear Interference process that has served us well in proton polarimetry. The analyzing power in pp elastic scattering was measured to be fairly constant from RHIC injection to the highest energy reached. The idea is to extend this to ^3He polarimetry beams. ^3He - Carbon polarimeters will be used for fast measurements, but these have to be calibrated using either a ^3He jet or possibly a storage cell to increase the target density. The ^3He beam calibration will rely on ^3He - ^3He elastic scattering and two identical particles process where the analyzing power is the same whether the target or the beam is polarized.

Of course, the jet or cell polarization will be measured using a separate process. The recoil scattering kinematics are similar to what we are using in proton polarimetry that the same equipment could be used interchangeably between proton and ^3He beams.

Study of the hadronization process from single hadron and hadron pair production in SIDIS at COMPASS

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Hadron production in hard scattering reactions is described by the hadronization process, which combines quarks into final-state hadrons. Within the theoretical framework of leading-twist collinear QCD, the cross section for hadron production in semi-inclusive reactions can be factorized into a hard scattering cross section describing the hard interaction at quark level and calculable in perturbative QCD and non-perturbative universal functions: collinear parton distribution functions which reflect the quark structure of initial-state hadrons and collinear fragmentation functions which encode details on the hadronization process. In the last decades, a major effort has been achieved on theoretical and experimental levels and allowed to constraint, with very high precision, parton distribution functions except strange quark distribution, which still carries large uncertainties. Fragmentation functions, however, remain at a very preliminary stage of study with a growing interest in accurate and precise knowledge.

Currently, single hadron fragmentation functions represent a key ingredient in accessing the nucleon longitudinal spin structure, and dihadron fragmentation functions, both polarized and unpolarized, are essential to access transversity function, an unknown corner in the nucleon spin structure. Dihadron fragmentation functions are also needed to investigate the in-medium effects in heavy ion collisions. Current knowledge of single hadron fragmentation functions is based on existing global QCD analyses driven by single inclusive electron-positron annihilation measurements, which are very precise and whose cross section have no dependence on parton distribution functions, making it a clean process for study of the hadronization process. However these data do not allow disentangling between quark and anti-quark fragmentation functions. In addition, measurements are performed in a quite limited range of energy scales. Complementary information on the hadronization process in a complementary energy regime and on the hadronization of quarks of different flavors is provided by semi-inclusive measurements in proton-proton and lepton-nucleon scattering. The latter have the advantage of covering a wide energy scale range and provide a larger sensitivity to the flavor dependence of fragmentation functions. Nowadays, while pion fragmentation functions are known with a limited precision and kaon fragmentation functions are poorly known, the situation for dihadron fragmentation functions turns out to be behind the schedule and no studies or measurements have been yet performed.

Measuring both single hadron and hadron pair multiplicities in semi-inclusive deep inelastic scattering at COMPASS represent a fundamental contribution towards a better understanding of the hadronization process and a first measurement for hadron pair multiplicities in SIDIS. These measurements will be presented and discussed.

Getting at the Gluon: The High Statistics $\pi^0 A_{LL}$ Measurement at PHENIX With Investigations of a Major Systematic Uncertainty

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Colliding protons head-on with helicity (longitudinal polarization) allows us to enhance the role of parton spin in their cross section and extract information about the gluon spin contribution to the proton, ΔG . For PHENIX, the double-longitudinal spin asymmetry A_{LL} at $\sqrt{s} = 200$ GeV in the mid-rapidity π^0 channel has proved to be most fruitful in this regard. However, in light of the systematic uncertainty on A_{LL} , in particular that in determining the relative luminosity between same and opposite helicity collisions, the statistical utility of the $\pi^0 A_{LL}$ measurement has been nearly exhausted in half of its p_T bins. In order to better understand this systematic, which we estimate through comparison of minimum bias triggers in our very forward detectors, we have begun investigating the consequences of the beams' paths and polarization directions in the interaction region. Specifically, as a first step we performed a scan of certain beam angles during transversely polarized running in 2012 and confirmed an effect that can mimic certain double-spin asymmetries in our Zero Degree Calorimeter. The future will bring accumulation of longitudinally-polarized luminosity at $\sqrt{s} = 500$ GeV, primarily for the investigation of sea-quark polarization through W boson measurements. Reduction of relative luminosity systematics could allow the ΔG program to thrive through this period and thus is a worthy goal.

COMPASS results on Collins and Sivers asymmetries for charged hadrons

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The study of transverse spin and transverse momentum structure of the nucleon is an important part of the scientific program of COMPASS, a fixed target experiment at the CERN SPS. Transverse spin effects in semi-inclusive Deep Inelastic Scattering have been studied using a 160 GeV/c momentum muon beam and transversely polarized nucleon targets. The measurements have been performed with polarised deuterons in 2002, 2003 and 2004, and polarised protons in the years 2007 and 2010. The final high precision results on the proton Collins and Sivers asymmetries for charged hadrons have shown clear signals both for positive and negative hadrons, and for positive hadrons only respectively. By now new results for the Collins and Sivers asymmetries for charged π 's and K's from the 2010 data have been produced and are shown here for the first time. The results are also compared with the previous COMPASS measurement and with the HERMES data.

Polarized ^3He Ion Source Development for RHIC

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Major scientific opportunities to study the structure of the nucleon arise if polarized neutron beams can be provided at the world's only polarized proton collider, namely RHIC at Brookhaven National Laboratory in New York, USA. For example, in measurement of the transverse spin asymmetry in Drell-Yan scattering, the Siverson function is predicted [1] to have opposite signs for u and d quark flavors. eRHIC, a potential future electron-ion collider [2] using RHIC, would utilize both polarized proton and neutron beams to carry out a precision test of the fundamental Bjorken Sum Rule [3]. Effective polarized neutron beams can be realized if beams of polarized ^3He can be added to RHIC. Thus, an effort is underway to inject polarized ^3He atoms into the newly commissioned Electron Beam Ionization Source at RHIC [4]. The atoms are polarized via metastability exchange optical pumping [5] and will be transferred into EBIS. The goal is to deliver approx. 3×10^{12} $^3\text{He}^{++}$ per sec at 70% polarization to RHIC.

The source is under development at MIT and an initial test of the principle at BNL is planned. The source design will be described and the status of the test summarized.

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References

1. Zhong Bo Kang, *Unraveling the transverse structure of nucleons*, talk at the Workshop on Opportunities for Polarized He-3 in RHIC and EIC, BNL, September 28-30, 2011.
2. Abhay Deshpande, Richard Milner, Raju Venugopalan, and Werner Vogelsang, *Ann. Rev. Nucl. and Part. Sci.* **55**, 165 (2005).
3. J.D. Bjorken, *Phys. Rev.* **148**, 1467 (1966).
4. J. Alessi and A. Zelenski, *ICFA Newsletter No. 30*, p. 39, April 2003.
5. F.D. Colegrove, L.D. Schearer, and G.K. Walters, *Phys. Rev.* **132**, 2561 (1963).

Spin versus helicity

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We develop a formalism in which the fermion's probability amplitude is expressed as a trace over spinor indices but using the spin concept instead of the helicity.

$$\bar{u}_\alpha(k, s) \cdots f_{\alpha\alpha} \cdots u_\alpha(k', s') \\ = \text{Tr}(\cdots f \rho)$$

$$\rho(k', s', k, s) = \frac{2\mathcal{N}_{s's'}}{1 + s's'\zeta_0\zeta'_0} \left(\frac{k'+m'}{2m'}\right) \left(\frac{1+s'\gamma^5 \not{s}'}{2}\right) \mathfrak{R}(\bar{k}', \bar{k}) \left(\frac{k+m}{2m}\right) \left(\frac{1+s\gamma^5 \not{s}}{2}\right) \\ \mathfrak{R} = \sqrt{\frac{mm'}{(k_0+m)(k'_0+m)}} (\gamma_0 + 1)$$

We then show the correspondance between the spin and the helicity formalisms thus retrieving in another way all results of the helicity formalism but in a simpler form. Our spin formulation is however more appropriate to processes having transverse polarizations: processes of increasing popularity. The helicity formalism may do the same work but only indirectly and using redundant intermediary steps. On the other hand certain observables such as dipole moments electric or magnetic are naturally expressed in terms of spin rather than helicity. The helicity formalism for its part, applies more to collision processes with specified helicities. But both formalisms have the advantage of making the amplitudes or even the squared amplitudes easily computable either analytically or symbolically, a consequence of the rewriting of the amplitudes as an overall trace over gamma matrices

Jefferson Lab with 12 GeV Polarized Electrons

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The Continuous Electron Beam Accelerator Facility at Jefferson Lab is in the middle of a substantial upgrade to the accelerator and to the experimental facilities. We will provide a precise status report of the project and a broadly based discussion of the physics program which the new facilities will enable.

DVCS on the Proton at HERMES

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This talk explores the impact that the HERMES experiment has had regarding knowledge of the Deeply Virtual Compton Scattering process. We discuss the various measurements that HERMES has contributed to the library of DVCS knowledge [1--3], with focus in particular on the recent high-precision beam spin and charge asymmetries [4]. We discuss the first measurement of BH/DVCS on a Delta resonance and its implications for the DVCS measurements published by HERMES over the past decade. We also discuss the significance that the HERMES measurements have had on the knowledge of Generalised Parton Distributions and the information that one can therefrom glean about nucleon structure.

References

1. A. Airapetian et al, *JHEP* 06 (2008) 066.
2. A. Airapetian et al, *JHEP* 06 (2010) 019.
3. A. Airapetian et al, *Phys. Lett.* B704 (2011) 15.
4. A. Airapetian et al, *JHEP* 07 (2012) 032.

To Polarization of Hyperons in Heavy Ion Collisions

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In heavy ion collisions at high energies a hot and dense matter is created. In overlap region of colliding nuclei the energy and nuclear density increases multiply. At Dubna project NICA collision energies $\sqrt{s} = 4 - 11 \text{ GeV}$ where the interaction time and overlap time of colliding nuclei nearly coincide that leads to maximal baryonic density at freezeout. At these energies in contrast to proton-proton and proton-nucleus collisions there have been discovered, so called, 'horn' effect - an enhanced non-monotonic yield of strange particles, positive kaons and hyperons. Due to a large current originating in semi-peripheral collisions of heavy nuclei a very strong magnetic field in direction perpendicular to the reaction plane is possibly created. The magnitude of magnetic field estimated in [1] for AuAu collisions at impact parameter $b = 4 \text{ fm}$ and $\sqrt{s} = 9 \text{ GeV}$ is about $eB = 0.1 \cdot m_\pi^2$ which is by 3 orders higher than in the surface of magnetar.

We assume that the strange particles yield at above energy range is due to the phase transition of nuclei in the overlap region from the baryonic to hyperonic state. Hyperons may acquire polarization in the strong magnetic field which can be determined from the angular distribution of hyperon decay products relative to the magnetic field - the direction perpendicular to the reaction plane:

$$\frac{dN}{d \cos \theta^*} \sim 1 + \alpha_H P_H \cos \theta^*, \quad (1)$$

where P_H is the hyperon polarization, α_H is the hyperon decay parameter, and θ^* is the angle between the three-momentum of the decay daughter in the hyperon rest frame and the direction of magnetic field. Moreover, the system produced in noncentral relativistic heavy ion collisions possesses large orbital angular momentum. Due to the spin-orbit coupling of QCD, this orbital motion may result in a net polarization of hyperons as well [2].

References

1. V. Skokov, A.Yu. Illarionov, V. Toneev, *Int.J.Mod.Phys.*, **A24**, 5925 (2009).
2. B.I. Ableev et al., *Phys.Rev.*, **C76**, 024915 (2007).

Spin Physics at NICA

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SPD-NICA project is under preparation at second interaction point of the NICA collider. The purpose of this experiment is the study of the nucleon spin structure with high intensity polarized light nuclear beams. The design of the collider can allow us to reach with proton beams a very high collision energy up to $\sqrt{s} \sim 26 \text{ GeV}$ with average luminosity up to $10^{31} - 10^{32} \text{ cm}^2/\text{s}$, and for deuteron beams: a collision energy per nucleon - up to $\sqrt{s} \sim 12 \text{ GeV}$, the average luminosity reaches up to $10^{30} - 10^{31} \text{ cm}^2/\text{s}$. It is of great importance that both proton and deuteron beams will be effectively polarized. All these advantages give us unique possibilities to investigate the nucleon spin structure and various polarization phenomena in wide kinematical range. The preliminary schemes of the SPD detector are also proposed.

Spin Filtering at COSY and perspectives for PAX

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The high physics potential of experiments with stored polarized antiprotons led to the proposal of the PAX¹ experiment (Polarized Antiproton eXperiment) for the High Energy Storage Ring (HESR) of the new FAIR facility at GSI (Darmstadt/Germany). It is proposed to polarize a stored antiproton beam by means of spin filtering by a polarized hydrogen gas target. The feasibility of spin filtering with protons using a transversely polarized hydrogen gas target has been demonstrated in the FILTEX experiment and recently confirmed at the COSY ring in Jülich. A spin filtering experiment using a longitudinally polarized hydrogen gas target is planned after the installation of a siberian snake in 2014.

Further measurements including the investigation of pd-breakup reactions² and a test of the time reversal (TRIC)³ are planned using the developed experimental setup.

A proposal for a spin-filtering experiment with antiprotons at AD/CERN⁴ has been submitted to the CERN SPS comitee to investigate the spin-dependence of the pbar-p end pbar-d interaction. This knowledge is necessary to properly design a dedicated Antiproton-Polarizer Ring.

References

1. *Antiproton-Proton Scattering Experiments with Polarization*, Technical Proposal for the HESR at FAIR, Jülich (2005), e-Print Archive: hep-ex/0505054.
2. *Measurement of Spin Observables in the p(pol)d(pol) Breakup Reaction*, Proposal 202 for COSY, Jülich (2011), available at <http://www.fz-juelich.de/ikp/pax/>.
3. *Test of Time-Reversal Invariance in Proton-Deuteron Scattering at COSY*, Proposal 215 for COSY, Jülich (2012), available at http://www2.fz-juelich.de/ikp/publications/List_of_all_COSY-Proposals.shtml
4. *Measurement of the Spin-Dependence of the $\bar{p}p$ Interaction at the AD-Ring*, Proposal for AD/CERN, Jülich (2005), available at <http://www.fz-juelich.de/ikp/pax/>.

BES-III status and results

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The BES-III experiment in Beijing takes data in tau-charm domain since 2009. For the moment the world largest samples of J/ψ , ψ' , ψ'' and ψ (4040) data have been collected. The current status and plans of the BES-III experiment will be presented. The overview of recent results of BES-III collaboration on light hadron, charm and charmonium physics will be given.

Stationary Bound States of Dirac Particles in Collapsar Fields

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It is the first time stationary bound states of elementary spin $\frac{1}{2}$ particles that do not decay with time are obtained for a Schwarzschild gravitational field using a self-conjugate Hamiltonian with a flat scalar product in a wide range of gravitational coupling constant.

In order to obtain a discrete energy spectrum, we introduce a boundary condition such that the radial current density of Dirac particles near the “event horizon” is zero.

The quantum-mechanical analysis shows a physical nonequivalence of the Schwarzschild metric which prohibits the classical particles to cross the “event horizon” and the metrics, which allows the particles to cross a gravitational radius (the Eddington-Finkelstein, Painlevé-Gullstrand, Finkelstein-Lemaitre, Kruskal metrics, the Schwarzschild metric in the isotropic coordinates). For the first case, the existence of stationary bound states of Dirac particles with a real energy spectrum is possible. For the second case, for all above metrics there are only complex energy levels of spin $\frac{1}{2}$ particles that decay with time.

The results can lead to revisiting some concepts of the standard cosmological model related to the evolution of the universe and interaction of collapsars with surrounding matter.

Status of the Super B project and beam polarization issues

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The paper presents the status of the Super B factory, which is now under construction in the campus of University of Rome "Tor Vergata". Application of the novel approach of the electron and positron beams collision called the Crab Waist scheme allows to reach an unprecedented peak luminosity of $10^{36} \text{ cm}^{-2} \text{ s}^{-1}$. Another important advantage of the project is the longitudinal polarization of the electron beam at IP. Relevant issues of spin dynamics in the SuperB collider are also discussed in the paper.

Search for permanent EDM of charged particles and nuclei at storage rings

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Searches for EDM offer a sensitivity to the Physics Beyond the Standard Model which is commensurate to, and even exceeding, that of the direct searches at LHC. The signal of EDM is a precession of the spin in an electric field, but unlike neutral atoms and neutrons, charged particles run away in electric fields and storage rings are a unique approach to the proton and deuteron and helion EDMs. Direct measurements of the latter are imperative to disentangle the completely unknown isospin properties of CP(T) violation and to establish the contribution to EDMs from nuclear forces. The modern theories of EDM do not preclude a case of pEDM and dEDM orders in magnitude larger than nEDM.

After a brief foray into status of half a century quest for nEDM and plans for future nEDM experiments, I will review a current status of the BNL and JEDI(Juelich) projects to search for EDMs at dedicated electrostatic (+magnetic) rings based on the frozen longitudinal spin technique (the projected sensitivity up to several units of 10^{-29} e-cm), and the JEDI plans of the first direct search for pEDM and dEDM at COSY (Juelich) as is based on the spin resonance technique with radiofrequency flipper with radial electric field. In the latter case one hopes for a sensitivity $\sim 10^{-24}$ e-cm, modest but still in the ballpark of theoretical predictions.

In all cases a show stopper is the spin precession time which is bounded from above by the Spin Coherence Time (SCT) and I report on the recent theoretical and experimental progress in this subject. One recent exciting finding is the Orlov-Semertzides idea to run the resonance spin flipper in the Wien-filter mode, which does not excite the unwanted betatron oscillations. I explain why and how the EDM-transparent radiofrequency Wien-flipper paradoxically still produces the EDM signal.

Some ideas on BNL and JEDI lattices will be reviewed. The opportune point is that much of the systematics of the pEDM, dEDM searches of direct relevance to both BNL and JEDI projects can be studied with magnetic resonance spin flippers at COSY, and I will discuss some of the recent findings from active experimentation at COSY and the importance of running magnetic resonance flippers in the Wien-filter mode.

Measurements of Forward Jet Production in Polarized pp Collisions at $\sqrt{s} = 500$ GeV

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A_NDY project at RHIC has been proposed to measure the analyzing power for Drell-Yan production. Test runs took place during polarized proton operations of RHIC at $\sqrt{s} = 500$ GeV in 2011 and 2012 with a model of the A_NDY apparatus in place. In total, an integrated luminosity of 9 pb^{-1} with beam polarization of $\sim 50\%$ was sampled. The primary detector components were hadron calorimeter (HCal) that spanned the pseudorapidity interval $2.4 < \eta < 4.0$ and small electromagnetic calorimeter (ECal). Basic goals for A_NDY test running were to establish the impact of a third interaction region on RHIC performance and to demonstrate HCal calibration. Energy scale of HCal was established using neutral pion reconstruction and checked with hadronic response. In addition, data with a trigger based on HCal energy sum were taken to study jet events. First measurements of analyzing power in the forward jet production will be reported.

The helicity conservation hypothesis and p-p elastic scattering

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At the absence of the quantitative theory of strong interaction at the soft $-t$ region the purpose of experimentalists is to fulfill the complete set of experiments in order to reconstruct 5 complex pp-elastic scattering amplitudes directly from data at the fixed s and $-t$. Up to now such program was completed at PSI, LAMPF, SATURNE and ZGS for pp-elastic scattering at momentum range between 1-6 GeV/c. With increasing energy such program becomes very challenging, since most of the measurements should be done with polarized beam and/or polarized target. The additional difficulty arises from necessity to make second scattering for measuring the spin tensors (for example, so called Wolfenstein parameters). For this reason one needs a new approach for untangling non zero observables. Such an approach may be based on the following factual knowledge.

The recent experimental data show that at sufficiently high energies the several observables directly related to the single and double spin flip interactions in pp-elastic scattering tend to disappear with increasing energy. For example, at $-t$ region $[0.2-1] (\text{GeV}/c)^2$ and momentum $p_t > 6 \text{ GeV}/c$ polarization decreases fastly. At RHIC energy $\sqrt{s} = 200 \text{ GeV}$ the asymmetry A_N and spin correlation parameters A_{NN} and A_{SS} become very small. Based on these and similar indications and on some theoretical models we assume that at the asymptotic energies the helicity conserving interaction in s-channel of elastic NN-scattering becomes paramount.

Postulating that the helicity conservation hypothesis (HCH) *іздравствуйте* the rule we analyze the pp elastic scattering at asymptotic energies and untangle the surviving polarization observables. Taking as the starting point the 59 spin observables

after applying the HCH we get 36 nonzero observables. The additional assumption about equality of two surviving non spin flip amplitudes leads to 27 non-zero observables. There are several relations between these observables further reducing their numbers to a few ones. Finally we should make measurements of several observables only in order to check the hypothesis and reconstruct the elements of scattering matrix. Some of these observables may be measured at the actually operating facilities while others require special experimental equipments. Being experimentally tested and proved the HCH might be used as the suggestive hint in selecting the spin parameters for measurements at high energy accelerators/colliders.

Measurement of longitudinal single spin asymmetry of $W^\pm \rightarrow \mu^\pm$
at forward/backward rapidities with PHENIX at
 $\sqrt{s} = 500 - 510$ GeV polarized p+p collisions

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Polarization of sea quarks in the proton is one of the important ingredients to the proton spin structure to be explored experimentally for understanding the spin structure of the nucleon. The RHIC accelerator collides polarized protons at $\sqrt{s} = 500 - 510$ GeV which enables W/Z boson production. The longitudinal single spin asymmetry of the cross section of W boson produced by the nature of parity-violating weak interaction is a probe to the sea quark polarization. The PHENIX Muon Arm covers the forward/backward rapidity range and measurement of spin asymmetry of $W^\pm \rightarrow \mu^\pm$ at this rapidity range will reveal the complementary information of the sea quark polarization together with mid-rapidity measurements.

The first data of 25 pb^{-1} for $W^\pm \rightarrow \mu^\pm$ were acquired in the run in 2011 at $\sqrt{s} = 500$ GeV collisions, with successfully upgraded muon trigger systems for observing this channel. In this talk, the first preliminary result of single spin asymmetry of $W^\pm \rightarrow \mu^\pm$ with these data as well as the current status of runs in 2012 will be presented.

Single Spin Asymmetry Measurements in Polarized Proton
Collisions at STAR

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Single spin asymmetries of particle hadroproduction and multi-particle correlations are known to be sensitive to quark polarization and partonic orbital angular momentum in a transversely polarized proton. To date, models trying to explain the origin of the observed asymmetry generally fall into two categories: transverse momentum dependent factorization and higher twist effects in collinear scheme. Various observables have been proposed thereby to probe different characteristics of the spin structure of proton, as well as to examine the validity and connections of the aforementioned models. We will present the status of recent STAR measurements on single spin asymmetries of hadron-jet correlations and di-hadron production at mid-rapidity in $\sqrt{s} = 200 \text{ GeV}$ pp collisions in order to extract proton transversity. We will also give an update on the asymmetry measurements at forward rapidity ($2.6 < \eta < 4$) for inclusive π^0 and η meson production in $\sqrt{s} = 500 \text{ GeV}$ pp collisions with p_T coverage from 0 to 10 GeV/c.

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Distinguishing Indirect Signatures of New Physics at the ILC with Polarized Beams: Z' Versus Anomalous Trilinear Gauge Couplings

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New heavy neutral gauge bosons Z' are predicted by many models of physics beyond the Standard Model. It is quite possible that Z' s are heavy enough to lie beyond the discovery reach of the CERN Large Hadron Collider LHC, in which case only indirect signatures of Z' exchanges may emerge at future colliders, through deviations of the measured cross sections from the Standard Model predictions. We discuss in this context the foreseeable sensitivity to Z' s of W^* -pair production cross sections at the e^+e^- International Linear Collider (ILC), especially as regards the potential of distinguishing observable effects of the Z' from analogous ones due to competitor models with anomalous trilinear gauge couplings that can lead to the same or similar new physics experimental signatures at the ILC [1]. The sensitivity of the ILC for probing the Z - Z' mixing and its capability to distinguish these two new physics scenarios is substantially enhanced when the polarization of the initial beams and the produced W^* bosons are considered.

References

1.V.V. Andreev, G. Moortgat-Pick, P. Osland, A.A. Pankov and N. Paver, preprint DESY-12-016, CERN-PH-TH-2012-077, May 2012, 33 pp., arXiv:1205.0866 [hep-ph].

Intraarticulation disorders in temporomandibular joint dysfunction patients

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Magnetic resonance image of temporomandibular joint (TMJ) provides images of condylar and disc and there position. It is impossible in X-ray pictures. This images are very important in diagnosis and treatment planning in TMG dysfunction patients[1,2]. Thirty-one patients with TMJ dysfunction were selected with intraarticular pain symptom. All subjects had bilateral magnetic resonance imaging scans. Twenty-one had displacement of the disc and condylar. Changes were found in condylar bone morphology: 16 had osteophytes and erosion, at 21 deformation of the condylar. At three patients were found symptoms of disc fragmentation.

References

1. A.M.Whyte, D.McNamara. I.Rosenberg, and A.W.Whyte. Magnetic resonance imaging in the avaluation of temporomandibular joint disc displacement- a review of 144 cases. *Int. J. Oral Maxillofac. Surg.* 2006, 35,696-703.
2. M. Wang, H. Cao, Y.Ge, and S.E.Widmalm Magnetic resonance imaging on TMJ disc thickness TMD patints: A pilot study. *J.Prosthet.Dent.* 2009, 102. Iss.2, 89-93.

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Study of TMDs with polarized beam and/or targets at HERMES

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For a long time, transverse-spin effects in hard processes have been considered to be negligibly small. It took a while until it was realized that theory allows for unsuppressed transverse polarization effects in the nucleon. In particular, it was recognized that the leading-twist collinear transversity distribution function contributes substantially to single transverse-spin asymmetries in Semi-Inclusive DIS (SIDIS) through the so-called Collins mechanism [1]. When the intrinsic transverse momentum p_T of the quarks is not integrated over, several new (transverse momentum dependent) parton distribution functions (TMDs) are needed for a complete description of the (non-collinear) structure of the nucleon. The quark transverse momentum couples naturally with the quark or the nucleon spin (spin-orbit correlations), resulting in a variety of azimuthal asymmetries measurable in SIDIS. In the last decade TMDs have been recognized as crucial ingredients for a complete understanding of the nucleon structure as they allow for a 3-dimensional description of the nucleon (nucleon tomography) in momentum space, and could provide insights into the yet unmeasured quark orbital angular momentum. Noteworthy, the interpretation of hard processes in terms of TMDs has been put on a solid basis by the proof of a non-collinear factorization theorem for SIDIS and Drell-Yan [2]. At leading twist eight TMDs enter the SIDIS cross section in conjunction with a fragmentation function (FF) [3]. Among them, particularly interesting is the Sivers function $f_{1T}^\perp(x, p_T^2)$ [4], describing the correlation between the quark transverse momentum and the nucleon transverse polarization. It is indirectly related to the quark orbital angular momentum and, similarly to the Collins mechanism, causes measurable azimuthal asymmetries in the direction of the final state hadrons (*Sivers effect*). Another intriguing TMD is the so-called *worm-gear* $g_{1T}^\perp(x, p_T^2)$ [5] function, describing the probability to find longitudinally polarized quarks within a transversely polarized nucleon. It can be accessed in SIDIS in A_{LT} double-spin asymmetries, requiring the joint use of a longitudinally polarized beam and a transversely polarized target. In the last years, many transverse-spin and transverse-momentum effects have been measured by the HERMES experiment. An overview of the most recent results obtained with the use of a polarized hydrogen target is presented.

References

1. J. C. Collins, Nucl. Phys. **B396**, 161 (1993).
2. X.-d. Ji, J.-P. Ma, and F. Yuan, Phys. Lett. **B597**, 299 (2004).
3. A. Bacchetta *et al.*, JHEP **02**, 093 (2007).
4. D. W. Sivers, Phys. Rev. **D41**, 83 (1990).
5. A.M. Kotzinian and P. J. Mulders, Phys. Rev. **D54**, 1229 (1996).

The TMD program at CLAS and CLAS12

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In recent years, Transverse Momentum Dependent parton distribution functions (TMDs) are being recognized as crucial ingredients for a complete understanding of the nucleon (non-collinear) structure. Describing correlations between the quark or the nucleon spin with the quark transverse momentum (i.e. spin-orbit correlations), TMDs allow for a 3-dimensional description of the nucleon structure in momentum space (nucleon tomography) and could provide insights into the yet unmeasured quark orbital angular momentum. Noteworthy, the interpretation of hard processes in terms of TMDs has been put on a solid basis by the proof of a non-collinear factorization theorem for Semi Inclusive Deep Inelastic Scattering (SIDIS) and Drell-Yan processes [1]. At leading-twist, eight TMDs contribute to the SIDIS cross-section in conjunction with a fragmentation function [2]. The CEBAF Large Acceptance Spectrometer (CLAS) [3] installed in the Hall-B of JLab, with its large acceptance, is particularly suitable for the reconstruction of final state hadrons, allowing the investigation of the SIDIS process in a wide kinematic range. At CLAS, TMDs are probed through the measurement of specific azimuthal modulations of the SIDIS cross-section using a 6 GeV polarized electron beam and unpolarized or longitudinally polarized NH_3 and ND_3 targets. An overview of the main CLAS results and their interpretation in terms of TMDs will be presented. In the 12 GeV era of JLab, high precision SIDIS data will be collected allowing a detailed study of TMDs in the valence region, i.e. in a kinematic domain (large- x) complementary to that exploited by the HERMES and COMPASS experiments. Several approved TMDs-related measurements will be performed with the CLAS12 apparatus [4], evolution of the CLAS spectrometer for the 12 GeV upgrade of the accelerator facility. Studies of TMDs at CLAS12 will benefit from a unique combination of wide kinematic coverage, high luminosity, high polarization and advanced detection capabilities, including a very good hadron identification. Projected results for single-hadron and di-hadron azimuthal single-spin asymmetries as well as for single-hadron double-spin asymmetries will be reported for various combinations of target and beam polarization and for various hadron types.

References

1. X.-d. Ji, J.-P. Ma, and F. Yuan, Phys. Lett. **B597**, 299 (2004).
2. A. Bacchetta *et al.*, JHEP **02**, 093 (2007).
3. B.A. Mecking (CLAS), Nucl. Instr. Meth. A **503**, 513 (2003).
4. *CLAS12 Technical Design Report (V5.1)*, JLab (2008)

Timelike Compton Scattering at JLab

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A broad program for studying the quark and gluon structure of hadrons, and in particular, probing nucleon structure using deeply virtual exclusive reactions and the formalism of Generalized Parton Distributions (GPDs) is underway at Jefferson Lab. Deeply Virtual Compton Scattering (DVCS), $ep \rightarrow e\gamma p$, has been the focus of interest as it provides the cleanest tool for accessing the quark GPDs of the nucleon. Time-like DVCS, also known as Time-like Compton Scattering (TCS), is the inverse process to space-like DVCS and is studied through the photoproduction of lepton pairs (l^-l^+). TCS can be an effective tool for studying the real part of the Compton amplitude. Combining space-like and time-like data thus offers additional constraints on the GPDs. Studies of lepton pair production are started at Jefferson Lab using 6 GeV CLAS data. In this report, preliminary results on angular asymmetries in TCS using CLAS 6-GeV electroproduction data will be presented. Recently a proposal for studying TCS and J/Ψ photoproduction using upgraded CEBAF machine and CLAS12 detector is approved by JLab Program Advisory Committee (PAC). The CEBAF 12 GeV upgrade will make it possible to reach di-lepton invariant masses of up to 3.4 GeV. This will allow to study TCS in the range of outgoing photon virtualities (Q^2) from 4 GeV² to 9 GeV² (above the light quark meson resonances and below charm threshold), and access the nucleon's gluonic structure at large x through J/Ψ photo- and electroproduction.

Transverse spin asymmetries beyond Collins and Sivers at COMPASS

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COMPASS is a fixed-target high energy physics experiment at the SPS at CERN [1]. One of the important objectives of the experiment is the exploration of the transverse spin structure of the nucleon via azimuthal asymmetries arising in the cross-section of deep inelastic scattering of polarized leptons off transversely polarized target nucleons. For this purpose a series of measurements have performed in COMPASS using a 160 GeV/c longitudinally polarized muon beam and transversely polarized ⁶LiD-deuteron (in 2002, 2003 and 2004) and NH₃-proton (in 2007 and 2010) targets.

Results obtained so far by the collaboration for the Collins and Sivers asymmetries play an important role in the general understanding of the three-dimensional nature of the nucleon in terms of Transverse Momentum Dependent (TMD) parton distribution functions (PDFs) and fragmentation functions (FFs). For instance, measurements done by COMPASS and HERMES experiments together with the BELLE experimental data allowed a first extraction of the *transversity* and *Sivers* TMD DFs and *Collins* FF.

In addition to these two measured leading-twist effects the SIDIS cross-section counts six more azimuthal effects, which have their own well defined leading order or higher-twist interpretation in terms of QCD parton model. Here are presented the preliminary results for these new asymmetries, obtained from COMPASS transverse deuteron and proton data.

References

1. P. Abbon *et al.* [COMPASS Collaboration], Nucl. Instrum. Meth. A 577 455 (2007).

The Form Factors of the Nucleons

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There has been much activity in the measurement of the elastic electromagnetic proton and neutron form factors in the last decade, and the quality of the data has been greatly improved by performing double-polarization experiments, in comparison with with previous unpolarized cross section data. Here we will review the experimental data base in view of the new results for the proton and the neutron, obtained at MIT-Bates, JLab and MAMI. The rapid evolution of phenomenological models triggered by these highprecision experiments will be discussed. In particular, the possibility that the proton is non-spherical in its ground state, and that the transverse charge density are model independently defined in the infinite momentum frame. Likewise, flavor decomposition of the nucleon form factors into dressed u and d quark form factors, may give information about the quark-diquark structure of the nucleon. The current proton radius crisis will also be discussed.

Approximation of Jet Axis in Rapidity Separated Dihadron Correlations

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The jet axis approximation method of particle track analysis presented here is an attempt to gain forward jet information in a novel way in the pseudorapidity range of 3.1 to 3.65 using the current PHENIX detector. Knowledge of the forward jet axis direction would allow for a measurement of the Collins effect at PHENIX which is not accessible with a purely central jet analysis due to small transversity at Bjorken x values sampled in the central region. This would be the first measurement of the Collins effect at forward rapidities at a polarized proton-proton collider. It is known that TMD factorization in general is broken in $p+p$ collisions. A comparison between measurements at RHIC and those from SIDIS experiments will help quantify the magnitude of factorization breaking effects in transversely polarized $p+p$ collisions.

The Polarized Target for the G_{Ep} and g_2^p Experiments at Jefferson Lab

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Solid polarized targets have been an important part of the physics program at Jefferson Lab, used in experiments to measure the spin structure of the nucleons as well as the electro-magnetic structure functions. Recently, two experiments were concluded in Hall A which utilized a solid, polarized hydrogen target. These experiments, which ran concurrently, were a measurement of the g_2^p structure function and a measurement of the proton electric form factor G_{Ep} . The experiments presented new challenges to the traditional solid target design. Logistical factors associated with switching back and forth between the two experiments rapidly and the special kinematic requirements of the experiments required an update to the standard Jefferson Lab polarized target, used in Hall C and previously at SLAC. The update to the target also addressed performance issues, especially at the lower than normal target magnetic fields needed for the g_2^p experiment. The results of these upgrades will be discussed, as will the overall target performance.

Probing TMDs through azimuthal distributions of pions inside a jet in hadronic collisions

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Within the framework of the so-called generalized parton model, which includes spin and intrinsic parton motion effects, assuming the validity of factorization for large- p_T jet production in hadronic collisions, we study the azimuthal distribution around the jet axis of leading pions produced in the jet fragmentation process. We identify the observable leading-twist azimuthal asymmetries, which are generated by all the physically allowed combinations of transverse momentum dependent (TMD) parton distribution and fragmentation functions [1]. In particular, we show how one can isolate the Collins and Sivers contributions and, adopting available information on the quark Sivers function, on the quark transversity distribution and on the Collins function, we provide estimates for these azimuthal asymmetries in kinematical configurations presently investigated at RHIC by the STAR Collaboration, for both central [2] and forward [3] rapidities. Finally, we suggest a test of the process dependence of the Sivers function by considering the effects of color-gauge invariant initial and final state interactions [4].

References

1. U. D'Alesio, F. Murgia and C. Pisano, Phys. Rev. D **83**, 034021 (2011).
2. R. Fatemi [STAR Collaboration], AIP Conf. Proc. **1441**, 233 (2012).
3. N. Poljak [STAR Collaboration], J. Phys. Conf. Ser. **295**, 012102 (2011).
4. U. D'Alesio, L. Gamberg, Z.-B. Kang, F. Murgia and C. Pisano, Phys. Lett. B **704**, 637 (2011).

Measurement of analyzing power for the reaction
 $p + \text{CH}_2$ at polarized proton momentum of 7.5 GeV/c
(ALPOM2 proposal)

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A measurement of the angular distribution of the analyzing power of the semi-inclusive reaction (pol)p+CH₂ to as high momentum as possible, is of the greatest interest and necessary for future experiments; a measurement at a proton momentum of 7.5 GeV/c will be most valuable.

With increasing energy the probability that all the particles of the final state are detected increases; it depends on particularities of the detector, like angular resolution, ability to select the leading particle, ability to reconstruct multi-particle events and so on. The largest analyzing power is obtained when the selected particle has the smallest scattering angle and the largest energy; this particle is then more likely to be the scattered incident particle.

The polarimeter ALPOM is constituted by two 12x12.5 cm² (25x25 cm²) drift chambers positioned before (after) the CH₂ target of dimensions 30x30x51.6cm³. An angular resolution better than 0.4 mrad can be obtained adding a plane of drift tubes. Scintillators placed upstream give the time signal.

Here we propose to improve the polarimeter response by adding a hadron calorimeter to the ALPOM setup. This hadron calorimeter, which will be located downstream from the polarimeter, will consist of 25 of the individual "bars" built 20 years ago in Dubna, and subsequently used in COMPASS at CERN.

The measurements are planned in next future, when the polarized deuteron source brought from Indiana will be operative at the VBLHEP accelerator complex. It will allow producing polarized proton beams by deuteron breakup. The measurement will be preceded by beam tests with unpolarized protons.

On QCD effects in precision analysis of angular observables of
the process $B \rightarrow K^* l^+ l^-$

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The LHCb experiment is now measuring a plenty of angular observables in the decay $B \rightarrow K^* l l$. In case of finding any deviation from the SM predictions - which is the hope and ultimate goal of every LHC experiments - these observables can provide a clue to the spin structure of new physics beyond the SM. The clear statement about the certain evidence of new physics requires high quality of experimental data and also very accurate predictions within the SM. In my talk the current theoretical precision of computation of some angular observables in the decay $B \rightarrow K^* l l$ is discussed. The theoretical precision is mainly limited by the necessity to compute hadronic matrix elements within QCD. I discuss in detail the contributions of soft gluons to the appropriate hadronic amplitudes and their influence on the uncertainty of SM predictions.

References

1. LHCb Collaboration (R Aaij (NIKHEF, Amsterdam) et al.) Phys. Rev. Lett. **108**, 181806 (2012)
2. A. Khodjamirian, T. Mannel, A. A. Pivovarov and Y. -M. Wang, JHEP **1009**, 089 (2010)

Measurements of Cross Section for High- p_t Hadron Production in Muon-Deuteron Collisions at $\sqrt{s} = 17$ GeV

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Differential cross-sections for semi-inclusive production of charged hadrons at a center-of-mass energy $\sqrt{s} = 17$ GeV were measured by the COMPASS experiment at CERN. The data, collected at the photo-production limit, $Q^2 < 0.1$ (GeV/c)², are presented in bins of pseudo-rapidity, from -0.1 to 2.4, and cover the hadron transverse momentum interval between 1 GeV/c and 3.5 GeV/c. The data are compared to a recent next-to-leading order (NLO) QCD calculation. While the fall-off of the calculated cross section is in good agreement with the measured slope, its overall normalization clearly under-predicts the data, by a factor of three to four. The observed disagreement indicates that terms beyond NLO in the QCD framework may significantly contribute to this process. The dependence of the cross section to the pseudo-rapidity and to the charge of the hadrons is also discussed.

Density matrix in technique of polarized ion sources

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The use of the density matrix is the most direct way to work with polarization parameters. The solutions of the equation for the density matrix are obtained for hydrogen and deuterium. The magnetic moments of nuclei are explicitly incorporated into the equations, even though numerically it does not make a big difference. We discuss the possible advantage of this method compared with the traditional one [1].

The spin-dependent part of the Hamiltonian for hydrogen atoms is given by

$$\hat{H}(t) = -\mu_e \vec{\sigma}_e \vec{B}(t) - \mu_p \vec{\sigma}_p \vec{B}(t) + \frac{\Delta W_p}{4} \vec{\sigma}_e \vec{\sigma}_p, \quad (1)$$

with $\Delta W_p = 1420$ MHz, $\mu_p = 1.411 \times 10^{-26}$ J/T.

For deuterium atoms:

$$\hat{H}(t) = -\mu_e \vec{\sigma}_e \vec{B}(t) - \mu_d \vec{S}_d \vec{B}(t) + \frac{\Delta W_d}{3} \vec{\sigma}_e \vec{S}_d, \quad (2)$$

with $\Delta W_d = 327$ MHz, $\mu_d = 0.433 \times 10^{-26}$ J/T,
and for electrons: $\mu_e = -928.5 \times 10^{-26}$ J/T.

As usual, the density matrix is evolved according to the equation:

$$i\hbar \frac{d\hat{\rho}(t)}{dt} = [\hat{H}(t), \hat{\rho}(t)]. \quad (3)$$

It is shown that in the general case the density matrix can not be reduced to the one with the only spin variables of the nucleus in contradiction with the statement of K. Blum [2] (eq. 3.2.6).

References

1. H. Paetz gen. Schieck, Nuclear Physics with Polarized Particles, Springer (2012).
2. K. Blum, Density Matrix Theory and Applications, cited from Russian translation, Mir, p.84 (1983).

Studies of basic limitations on production, transport and acceleration of the high intensity polarized H^- beam in the RHIC polarized ion source

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Basic limitations on the high-intensity H^- ion beam production were experimentally studied in charge-exchange collisions of the neutral atomic hydrogen beam in the Na-vapor jet electron capture cell. These studies are the part of the polarized source upgrade project for RHIC (up to 10 mA peak current and 85% polarization). The expected manifold rise of polarized protons output in the upgraded scheme of OPPIS [1] will be achieved due to geometrical focusing of the atomic hydrogen beam of a 4-8 keV energies and very high equivalent current up to 4 A at the axis of superconductive solenoid with field of 3T. This new scheme allows us to study the conversion of very high density H^0 beams into H^- in Na-vapor jet cell. The experiments have revealed the limitation for the output current density of negative ions at a level significantly lower than the expected value for the electron capture at the sodium equilibrium target. The limitation becomes stronger with the decreasing of the beam energy (3-4 keV). The experimental results show that the limitation mechanism is connected with the influence of beam space charge and beam induced instabilities during its interaction with background plasma. To overcome the space charge limitation it's necessary to compensate the negative space charge. The compensation should be done rapidly because of pulsed character of the source regime. Xe, because of its chemical inactivity, large mass, rather low ionization potential, and high ionization cross-section, is supposed to be one of the most convenient substances for the gas compensation of the negative ion beam space charge. The required concentration of injected Xe increases with the decrease of beam energy. It has been found that in the working energy range of OPPIS the injection of Xe gas into sodium vapor jet permits to

overcome basic limitations of beam divergence under its space charge and to suppresses the most savior beam instabilities.

References

1. A. Zelenski et al., Rev. Sci. Instr., 73, pp. 888-891 (2002)

Status of Polarized Electron Beams at Jefferson Lab

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This submission provides an update on research activities at Jefferson Lab devoted to improving the performance of DC high-voltage GaAs photoguns. These activities improve the physics reach at the Continuous Electron Beam Accelerator Facility, and support new accelerator initiatives like the Electron-Ion Collider that will rely on electron sources with capabilities beyond today's state-of-the-art. Recent efforts at Jefferson Lab have focused on meeting the demands of parity-violating electron scattering experiments, conducting experiments at high average current to clearly identify lifetime-limiting mechanisms, improving vacuum, operating the photogun at significantly higher voltage (200+ kV) and using a spin-polarized electron beam at 8 MeV to produce spin polarized positrons.

Recent results and achievements with CLAS

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An overview of the recent results obtained by the CLAS collaboration at the Jefferson Laboratory will be presented. Special emphasis will be placed on the study of GPDs and TMDs, which can be accessed through measurements in exclusive and semi-inclusive DIS respectively.

QCD and SPIN Effects

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I will review recent progress in understanding SPIN phenomena in the framework of QCD. Progress in derivation of QCD evolution of non collinear parton distributions, TMDs and multy-parton correlations will be also reviewed. Phenomenological results and impact of future experimental facilities will be presented.

Calculation of spin resonance harmonics in an accelerator with Snakes and rotators

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The calculation of resonance strength by DEPOL code assumes an accelerator with vertical magnet field on the design orbit. In this work, the ASPIRRIN code has been extended to provide the calculation of resonance harmonics for the case of machine with Siberian Snakes and spin rotators. The resonance harmonic calculations for different cases of RHIC accelerator configuration are shown and discussed, including the case of the configuration with more than two Snakes per RHIC ring.

Proton Form Factor Measurements at Jefferson Lab, Past and Future

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The increasingly common use of the double-polarization technique to measure the nucleon form factors, in the last 15 years, has resulted in a dramatic improvement of the quality of all four nucleon electromagnetic form factors, G_{Ep} , G_{Mp} , G_{En} and G_{Mn} . It has also completely changed our understanding of the proton structure, having resulted in a distinctly different Q^2 -dependence for G_{Ep} and G_{Mp} , contradicting the prevailing wisdom of the 1990's based on cross section measurements and the Rosenbluth separation method, namely that G_{Ep} and G_{Mp} obey a "scaling" relation $\mu G_{Ep} \sim G_{Mp}$. A direct consequence of the faster decrease of G_{Ep} revealed by the Jefferson Lab (JLab) polarization results was the disappearance of the early scaling $F_2/F_1 \sim 1/Q^2$ predicted by perturbative QCD.

In two earlier experiments, GEp(1) and GEp(2), in Hall A at JLab, the ratio of the proton's electromagnetic elastic form factors, G_{Ep}/G_{Mp} , was measured up to four momentum transfer Q^2 of 3.5 GeV² and 5.6 GeV², respectively, with high precision using the recoil polarization technique. The discovery that the proton form factor ratio measured in these two experiments decreases approximately linearly with four-momentum transfer, Q^2 , for values above ≈ 1 GeV², is one of the most striking results to come out of JLab.

A third experiment, GEp(3), was done in Hall C at JLab. It extended the Q^2 range to 8.54 GeV². The interesting feature of the results from GEp(3) is that the linearly decreasing trend observed in the data from GEp(1) and GEp(2) experiments appears to be slowing down.

There is an approved experiment, GEp(5), to continue these measurements to 15 GeV². A dedicated experimental setup, the super bigbite spectrometer (SBS), will be built for this purpose. It will be equipped with a focal plane polarimeter to measure the polarization of the recoil protons. The scattered electrons will be detected in an electromagnetic calorimeter.

In this presentation, I will review the status of the proton elastic electromagnetic form factors and discuss a number of theoretical approaches to describe these form factors.

Polarised Drell-Yan measurements at COMPASS-II

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The spin structure of the nucleon including the Parton Distribution Functions (PDFs) is an important subject studied by the COMPASS experiment at CERN. The transverse momentum dependent parton distribution functions (TMD PDFs) of the proton and deuteron from Semi-Inclusive Deep Inelastic Scattering (SIDIS) have been studied so far. The Drell-Yan (DY) process is a complementary way to access the TMD PDFs, using a transversely polarised target. Studying the angular distributions of dimuons from the DY events produced in the collisions of a negative pion beam with 190 GeV/c momentum off a transversely polarised proton target (NH₃) we are able to extract the azimuthal spin asymmetries, each containing a convolution of two PDFs, one from the target quark and one from the beam anti-quark. Disentangling these two PDFs we can access four of the eight TMD PDFs needed to describe the nucleon structure at leading order QCD, like the Sivers and the Boer-Mulders functions. The opportunity to study, in the same experiment, the TMD PDFs from both SIDIS and DY processes is unique at COMPASS. The expected sign change in Sivers and Boer-Mulders functions when accessed by DY and SIDIS will be checked [1,2]. The COMPASS II Proposal [3] was approved by CERN for a first period of three years including one year for polarised DY; the DY data taking is scheduled for 2014 and maybe it can be resumed for one more year in 2017. The feasibility of the measurement was proven by several beam tests done so far. The last one was performed in 2009, using a hadron absorber prototype downstream of the target and a high intensity pion beam, to understand the absorber and spectrometer response, radiation doses, and also to check our Monte-Carlo simulations. COMPASS aims to perform the first polarised DY experiment in the world.

References

1. J.C. Collins, Phys. Lett. **B536**, 43 (2002)
2. J.C. Collins, talk at LIGHT CONE 2008N
3. COMPASS Coll., "COMPASS-II proposal", CERN-SPSC-2010-014, SPSCP-340, 17 May 2010

Spin physics at A Fixed-Target Experiment at the LHC (AFTER@LHC)

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We report on the spin physics at a future multi-purpose fixed-target experiment with the proton or lead ion LHC beams extracted by a bent crystal. The LHC multi-TeV beams allow for the most energetic fixed-target experiments ever performed, with pp , pd and pA collisions at $\sqrt{s_{NN}} \simeq 115$ GeV and PbA collisions at $\sqrt{s_{NN}} \simeq 72$ GeV [1,2,3]. AFTER – for A Fixed-Target Experiment – gives access to new domains of particle and nuclear physics complementing that of collider experiments, in particular that of RHIC and the projects of electron-ion colliders. The luminosity achievable with AFTER using typical targets surpasses that of RHIC by more than 3 orders of magnitude. The polarisation of hydrogen and nuclear targets allows for an ambitious spin program, including measurements of the QCD lensing effects which underlie the Sivers single-spin asymmetry, the study of transversity distributions and possibly of polarized parton distributions. The fixed-target mode also has the advantage to allow for measurements in the target region, namely at large x^\uparrow .

References

1. S. J. Brodsky, F. Fleuret, C. Hadjidakis and J. P. Lansberg, arXiv:1202.6585 [hep-ph].
2. J. P. Lansberg, S. J. Brodsky, F. Fleuret and C. Hadjidakis, *Few Body Syst.* **53**, 11 (2012).
3. J. P. Lansberg, V. Chambert, J. P. Didelez, B. Genolini, C. Hadjidakis, P. Rosier, R. Arnaldi and E. Scomparin *et al.*, arXiv:1207.3507 [hep-ex].

Search for permanent Electric Dipole Moments of light ions (p , d , ^3He) in storage rings

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The Standard Model (SM) of Particle Physics fails to explain the reason for our very existence since it is not capable to account for the apparent matter-antimatter asymmetry of our Universe. Physics beyond the SM is required and is searched for by (i) employing highest energies (e.g., at LHC), and (ii) striving for ultimate precision and sensitivity (e.g., in the search for electric dipole moments (EDMs)). Permanent EDMs of particles violate both time reversal (T) and parity (P) invariance, and are via the CPT -theorem also CP -violating. Finding an EDM would be a strong indication for physics beyond the SM, and pushing upper limits further provides crucial tests for any corresponding theoretical model, e.g., SUSY. For about half a century, neutron EDM (nEDM) measurements at many laboratories worldwide are trying to extend the already impressive experimental limits even further. Searches for EDMs of the proton, the deuteron, and of heavier nuclei bear the potential to reach even higher levels of sensitivity ($\sim 10^{-29}$ e-cm). Since it is essential to perform EDM measurements on different targets in order to unfold the underlying physics, pEDM and dEDM searches are must-do experiments. EDM experiments with charged particles are only possible at storage rings. In the ultimate experiment with a sensitivity beyond $\sim 10^{-29}$ e-cm, the EDM signal would be the vertical polarization produced by the EDM-induced precession of the frozen horizontal spin in a permanent radial electric field of a dedicated electric storage ring. For an all electric storage ring for protons, this goal is pursued by the srEDM collaboration based in the USA, while the newly found Jülich-based JEDI collaboration is pursuing an approach that shall employ eventually a combined electric-magnetic lattice which will allow access to protons, deuterons, and ^3He ions.

As an intermediate step, a first direct measurement of the EDMs of protons and deuterons at $\sim 10^{-24}$ e-cm sensitivity level will be carried out in the conventional magnetic storage ring COSY of Forschungszentrum Jülich. Here the EDM signal would be the horizontal polarization produced by the EDM-induced precession of the frozen vertical spin in a radio-frequency electric flipper with horizontal electric field. Apart from providing the first direct access to pEDM and dEDM, literally all the outstanding technological and instrumental challenges for the proposed studies at COSY constitute groundbreaking work for the next generation of dedicated electric storage rings. The research environment at Jülich coupled to the strong experienced groups of scientists and engineers from Jülich, RWTH-Aachen, BNL, and other major institutions from around the world, provides an ideal starting point, and constitutes on a world-wide scale, the optimal basis for one of the most spectacular possibilities in modern science: Finding a signal for new physics beyond the Standard Model through the detection of permanent electric dipole moments in a storage ring.

Study of Heavy Hyperons Production in DIS at COMPASS

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The yields of heavy hyperons and antihyperons have been studied in deep inelastic scattering at the COMPASS experiment at CERN. About 3.1×10^8 DIS events were collected in 2003-2004 data taking runs using a 160 GeV polarised muon beam scattered off a large polarised ${}^6\text{LiD}$ target. Signals from $\Sigma^+(1385)$, $\Sigma^-(1385)$, $\bar{\Sigma}^-(1385)$, $\bar{\Sigma}^+(1385)$, $\Xi^-(1321)$ and $\bar{\Xi}^+(1321)$ decays were reconstructed. The ratios of Σ^\pm/Λ , $\bar{\Sigma}^\pm/\bar{\Lambda}$, Ξ^-/Λ and $\bar{\Xi}^+/\bar{\Lambda}$ were determined. The measured yields were used to tune the parameters of the LEPTO generator simulating the DIS events. Comparison with the yields of the heavy hyperons in the low Q^2 region was done.

Neutron interference effects on a rotating earth

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It has been known for many years that neutron interference experiments are sensitive to the earth's gravitational field, and also to its rotation ('neutron Sagnac effect'). These effects are shown to follow from the Kerr space-time metric, using a geometric argument which has parallels with the Bohm-Aharonov effect.

Unpolarized azimuthal asymmetries in SIDIS at COMPASS

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The study of the spin structure of the nucleon and of the effects due to the quarks transverse momentum are part of the scientific program of COMPASS, a fixed target experiment at the CERN SPS. The azimuthal modulations which appear in the cross-section of SIDIS off unpolarised targets give insight on the intrinsic momentum structure of the nucleon and on the possible correlation between transverse spin and transverse momentum of the quarks. We present the results for the amplitudes of the $\cos(\phi)$, $\cos(2\phi)$, and $\sin(\phi)$ modulations (where ϕ is the azimuthal hadron angle in the gamma-nucleon system) obtained from the COMPASS data collected with a 160 GeV/c positive muon beam impinging on a deuteron target. The amplitudes are measured for both positive and negative hadrons, and the results on the dependence of the relevant kinematical variables obtained after a multi dimensional analysis are also presented.

Overview of recent results from the HERMES experiment

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HERMES has taken a wealth of deep-inelastic scattering (DIS) data using the 27.6 GeV polarized lepton beam at HERA and various pure gas targets, both unpolarized and polarized, which opened the door to several unique results. Among them are the first evidences for the naive-T-odd Sivers and Collins effects but also the recent first measurements of azimuthal modulations in the unpolarized semi-inclusive DIS cross section for charged kaons and pions and of beam-helicity asymmetries in exclusive leptonproduction of real photons using recoil-proton detection. An overview of HERMES results will be given with emphasis on the exploration of the three-dimensional structure of the nucleon.

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Complete Set of Deuteron Analyzing Powers for dp Elastic Scattering at Intermediate Energies

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Study of three nucleon forces (3NFs) is essentially important in clarifying nuclear phenomena. In addition to the first signals of the 3NF effects in the binding energies of the ^3H and ^3He , the significance of 3NFs has been recently pointed out for descriptions of discrete states in higher mass nuclei. Three nucleon scattering at intermediate energies ($E/A \sim 200$ MeV) is one attractive approach to investigate the dynamical aspects of 3NFs, such as momentum and/or spin dependences. With the aim of clarifying roles of the 3NFs in nuclei the experimental programs with polarized deuterons beams at intermediate energies are in progress at RIKEN RI Beam Factory (RIBF). As the first step, we have measured a complete set of deuteron analyzing powers (iT_{11} , T_{20} , T_{21} , T_{22}) in deuteron-proton (dp) elastic scattering at 250 and 300 MeV/nucleon.

The vector and tensor polarized deuteron beams were accelerated by three cyclotrons, AVF, RRC and the newly constructed cyclotron SRC. At RIBF spin symmetry axis of deuteron beams was controlled by the spin rotator Wien Filter prior to acceleration. Single turn extractions of the deuteron beams were achieved all for the three cyclotrons. Therefore the polarization amplitudes were maintained during acceleration. The measurement of deuteron analyzing powers for elastic dp scattering was carried out using the polarimeter BigDpol installed at the extraction beam line of the SRC. The deuteron beams bombarded a polyethylene (CH_2) target in the scattering chamber. Scattered deuterons and recoil protons were detected by plastic scintillators in kinematical coincidence conditions. The beam polarizations were monitored with the beam line polarimeter Dpol prior to acceleration by the SRC and they were 80% of the theoretical maximum values. In the presentation we will report on a complete set of deuteron analyzing powers, comparing with the recent theoretical predictions with or w/o 3NFs [1].

References

1. K. Sekiguchi *et al.*, Phys. Rev. C **83**, 061001 (2011).

The structure of nucleons and description of the electromagnetic form factors

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The comparison of different sets of the PDFs structure functions with the description of the whole sets of experimental data of electromagnetic form factors of the proton and neutron is made in the frame work of our model [1] of t -dependence of generalized parton distributions (GPDs) and the some other models. It is shown that despite a small difference of the description of the inelastic processes by the different sets of the PDF there is an essentially large difference in the description of electromagnetic form factors of the nucleons. The gravitation form factors, obtained with the different sets of the PDF, are also calculate and the anomalous gravimagnetic moment is compared with the Equivalence Principle.

References

1. O.V. Selyugin, O.V. Teryaev Phys. Rev. D**79**, 033003 (2009).

Magnetic moments of the Λ resonances within the framework of the chiral quark model

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The magnetic moments of the low-lying resonances $\Lambda(1405) 1/2^-$ and $\Lambda(1520) 3/2^-$ are calculated in the SU(6) quark model and chiral constituent quark model. In case of the chiral quark model, we have evaluated the contribution coming from the valence quarks as well as from the sea quarks obtained from the fluctuation process based on the emission of Goldstone bosons from the quarks. We have found that the major part of the magnitude associated to the magnetic moment of the states studied has its origin in the valence quarks, however, the contribution from the sea quarks reduces the overall magnitude.

The results found are compared with those obtained from the non-relativistic quark model and those of unitary chiral theories, where some of these states are generated through the dynamics of two hadron coupled channels and their unitarization. Although some features, like the sign of the magnetic moment of these two states are common in both models, the difference in magnitude reveals the different nature involved for these states within the two models. Measurements of these magnetic moments will be of great help in understanding the structure and nature of these resonances.

Two examples of in-flight spin flippers

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By experiments with polarized beam is very often appear an necessity to from time to time to change beam polarization on opposite. If such operation does not change other beam parameters, it helps to avoid or minimize some systematic errors. It's especially important in experiments, where spin dependent effect is small enough. This paper describes two set of equipments, that make spin flip for extracted beams. In both cases, these devices are absolutely distinct, because they are appropriate for different particles and at different energy range.

- The first of them is intended for future muon (g-2) experiment, which is under preparation now at JPARC. Here, the muon spin flip will be done by chain of electrostatic and magnetic bends at the kinetic energy 340 KeV. A beam matching is provides by a number of short solenoids
- The other flipper (or Siberian snake) will rotate spin protons or antiprotons, which come from Λ -meson decay with the energy 40 GeV. This experiment (#24) is planed at IHEP, Protvino. In this case, two superconducting helical magnets with opposite helicities and magnetic field 4.5 T will be used. To correct beam trajectory, additional dipole correctors are required.

System for tagging almost-real photons at VEPP-3 storage ring

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At VEPP-3 storage ring the work on construction of the system for tagging almost-real photons (PTS) is in progress. The tagging system will extend the possibilities for photoreaction studying at VEPP-3 significantly. The energy of tagging photons can be up to 1.5 GeV, energy resolution is better than 1%. PTS would allow to perform a complete kinematics reconstruction, thus permitting a reliable rejection of the background processes; to extend the measurements to higher photon energy; to determine the linear polarization of photon, thus enabling Sigma-asymmetry measurements and double polarization experiments (with linear polarized photon beam and tensor polarized deuterium target).

We discuss the status of tagging system and opportunities for photo-nuclear experiments with PTS.

QCD analysis of DIS and SIDIS data with two alternative methods

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The global fit analysis of all published data on DIS and semi-inclusive DIS (SIDIS) asymmetries is performed in the next to leading (NLO) QCD order. The respective parametrization on polarized PDFs is constructed. The especial attention is paid to the impact of novel SIDIS data on the polarized gluon distributions. The first moments of these distributions entering the nucleon spin occur surprisingly small quantities. The alternative direct (free of any fitting procedure) method of NLO QCD analysis is elaborated. Method is especially important for analysis of SIDIS data because it allows to avoid the problems arising in the conventional fitting procedure: functional arbitrariness at initial scale and ambiguities in the error band calculation. Within the alternative method the central values and uncertainties of the measured asymmetries directly propagate to the central values and uncertainties of the polarized PDFs we are interested in. The method is applied to all existing SIDIS data on pion production for an estimation in NLO QCD of the valence and sea quark contributions to the proton spin. As a result one arrives at the conclusion that, contrary to the valence contributions, the sea contributions to the proton spin are compatible with zero within the errors.

The Spin Physics $x_T \sim 1$ at $\sqrt{s_{NN}} < 10$ GeV: Problems and Decisions

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The energy range $\sqrt{s_{NN}} < 10$ GeV at $x_T \sim 1$ has left many puzzles of spin observables.

Significant spin effects in this energy do not vanish with growing of energy. Till now there are no understandings of the nature of these effects. It is naturally to carry out detailed studies the spin effects in this energy range to discover the nature of observable effects. In the talk is considered the program of studies with the polarized and nonpolarized beams at energy $\sqrt{s_{NN}} < 10$ GeV, which will allow to make it clear the nature of observable significant spin effects.

Measurement of T-violating Transverse Muon Polarization in $K^+ \rightarrow \mu^+ \pi^0 \nu$ Decay at J-PARC

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As a precision-frontier experiment at J-PARC, we are now proposing a search for time reversal invariance violation by measuring the transverse muon polarization (P_T) in the $K^+ \rightarrow \mu^+ \pi^0 \nu$ ($K \mu 3$) decays which constitutes a T-odd observable. This observable is one of the few test of T-invariance and the corresponding CP violation in non-neutral meson sector and is sensitive to direct CP violation. At J-PARC, we aim to improve the precision of this measurement (TREK experiment) by a factor of 20 comparing with the best result from our own KEK-PS-E246 experiment [1], and reach a limit of $\Delta P_T \sim 10^{-4}$ [2].

The final state interaction contributions in the SM descriptions are significantly smaller than the sensitivity of this experiment. On the other hand, several exotic models inspired by Multi-Higgs mechanism etc. predict sizable P_T values within the sensitivity attainable to us. Thus, this experiment is likely to find new source of CP violation, if any of these models are viable. Since it will certainly constrain the parameter space of the candidate models, the sensitivity of this experiment is comparable or superior to that of the proposed new neutron EDM experiment and other rare decay processes. The physics potential in terms of discovery of new physics along with the power to constrain the exotic model is shown to be competitive with other experiments being planned or prepared.

It is pointed out that the improved sensitivity will be achieved thanks to the new J-PARC facility beam quantities, namely, the newly designed low-momentum K^+ beam line. The experiment will use a stopped K^+ beam in conjunction with the upgraded E246 setup. Major changes of the detector system are 1) improved charged particle tracking by incorporating GEM detectors, 2) new readout of the CsI(Tl) calorimeter with APD, 3) introducing active polarimeter for the e^+ measurement from muon, and 4) a new magnet to

hold the muon spin polarization. This arrangement with increased K^+ beam intensity and a runtime of 10^7 seconds will improve the E246 result by a factor of 20, bringing the discovery potential to $\Delta P_T < 2 \times 10^{-4}$ in our quest for new physics. Details of the TREK experiment will be presented.

References

1. M. Abe *et al.*, Phys. Rev. **D73**, 072005 1-34 (2006).
2. The TREK(E06) proposal, <http://trek.kek.jp/proposal/> .

Measurement of the spin correlation coefficients $A_{x,x}$ and $A_{y,y}$ in the $pn \rightarrow \{pp\}_s \pi^-$ reaction near the threshold at ANKE-COSY

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A kinematically complete double polarization measurement of the $pn \rightarrow \{pp\}_s \pi^-$ process near the threshold has been performed recently at the ANKE-COSY spectrometer (Jülich). The experiment aimed to determine the spin correlation coefficients $A_{x,x}$ and $A_{y,y}$ in this process [1]. These results will facilitate further development of χPT in this sector [2-3].

The transversely vector polarized deuteron beam and the hydrogen internal polarized ANKE target were used in the experiment. The $pd \rightarrow d\pi^0$ process data were recorded concurrently and used for beam and target polarimetry. Independently, the product of the beam and target polarizations can be estimated using the properties of $A_{x,x}$ and $A_{y,y}$ coefficients. The polarized target was equipped with a storage cell that was the main source of background events. Dedicated expositions with no gas in the cell and with the cell filled with N_2 gas, were taken to study the backgrounds. The data analysis procedure and the first results of the experiment will be presented.

References

1. S. Dymov, COSY proposal #205 (2011).
2. C. Hanhart *et al.*, Phys. Rep. **397**, 155 (2004).
3. V. Baru *et al.*, Phys. Rev. C **80**, 044003 (2009).

Importance of the Fragmentation Functions in Determining Polarized Parton Densities

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In contrast to the unpolarized case, due to the lack of the charged current neutrino reactions on a polarized target the experiments on *inclusive polarized* deep inelastic lepton-hadron scattering (DIS) can fix only the sums of polarized quark and antiquark parton densities ($\Delta q + \Delta \bar{q}$)(x, Q^2). In order to separate them one has to involve in the QCD analysis of the data the semi-inclusive DIS processes (SIDIS) where a hadron is detected in the final state. In order to perform such an analysis, however, an accurate knowledge of the fragmentation functions (FFs), which describe the probability for a parton to form a given hadron, is needed.

It turned out that the results on the polarized sea quark densities strongly depend on the choice of the set of FFs presented in the literature [1]. In particular, we came to the so called "strange quark polarization puzzle", i.e. the contradiction between the negative polarized strange quark density obtained from all analyses of inclusive DIS data [2] and the positive values obtained from combined analyses of inclusive and semi-inclusive DIS data [3] using the de Florian et. al. (DSS) set of fragmentation functions.

Recently the HERMES and COMPASS collaborations presented their preliminary data on the pion and kaon multiplicities in the unpolarized SIDIS processes. The predictions corresponding to calculations using different sets of FFs available at present are not in agreement with the data. The question how important are the HERMES and COMPASS data on multiplicities for a more reliable determination of FFs and a possible resolution of the strange quark polarization puzzle is discussed.

References

- [1] E. Leader, A.V. Sidorov, and D.B. Stamenov, Phys. Rev. **D84**, 014002 (2011).
- [2] M. Hirai, S. Kumano, and N. Saito (Asymmetry Analysis Collaboration), Phys. Rev. **D74**, 014015 (2006); E. Leader, A.V. Sidorov, and D.B. Stamenov, Phys. Rev. **D75**, 074027 (2007); J. Blumlein and H. Böttcher, Nucl. Phys. **B841**, 205 (2010).
- [3] D. de Florian, R. Sassot, M. Stratmann, and W. Vogelsang, Phys. Rev. **D80**, 034030 (2009); E. Leader, A.V. Sidorov, and D.B. Stamenov, Phys. Rev. **D82**, 114018 (2010).

Dirac particle spin in strong gravitational fields

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Spin motion of Dirac particles in arbitrary strong gravitational fields is discussed. The general Hermitian Dirac Hamiltonian is derived and transformed to the Foldy-Wouthuysen representation. The quantum mechanical equations of spin motion are obtained and their classical limit is analyzed. The agreement between the quantum mechanical and classical equations is shown. The helicity dynamics is considered.

Measurement of proton beam polarization and A_N with pp and pC recoil polarimeters at RHIC

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At the Relativistic Heavy Ion Collider (RHIC) the measurement of the proton beam polarization is carried out by polarimeters whose operation is based on the detection of recoil products from proton-proton (pp) and proton-Carbon (pC) elastic scatterings. The pp polarimeter with a highly polarized hydrogen jet target provides an absolute scale for the polarization measurement; while the pC polarimeters are capable of providing a quick feedback on the beam intensity and polarization profiles. In the latter ultra thin carbon targets are quickly moved through the beam to measure the profiles in horizontal and vertical directions. In addition to providing the RHIC experiments with polarization numbers, the polarimeters also offer a unique knowledge of the analyzing power A_N in the kinematic region where the electromagnetic force is comparable in strength with the nuclear one (the Coulomb Nuclear Interference region).

In this report we present the measurement of proton beam polarization conducted in 2012 using a refined analysis strategy [1]. We inspect our data against a possible spin dependent hadronic contribution [2,3] to the measured transverse asymmetry. We discuss the overall performance of the RHIC polarimeters and the major systematic effects affecting the measurements.

References

1. <http://www.phy.bnl.gov/cnipol/>
2. N. H. Buttimore, B. Z. Kopeliovich, E. Leader, J. Soffer and T. L. Trueman, "The spin dependence of high-energy proton scattering," *Phys. Rev. D* **59**, 114010 (1999)
3. B. Z. Kopeliovich and T. L. Trueman, "Polarized proton nucleus scattering," *Phys. Rev. D* **64**, 034004 (2001)

Deeply Virtual Compton Scattering from the Neutron with CLAS and CLAS12

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Generalised Parton Distributions (GPDs) offer an insight into the three-dimensional structure of the nucleon and its internal dynamics, relating the longitudinal momentum of quarks to their transverse position. A very effective means of accessing GPDs is via measurements of polarisation-asymmetries in Deeply Virtual Compton Scattering (DVCS), in which a high energy electron scatters from a single quark in the nucleon and a photon is produced as a result. Measurements on both the neutron and proton are required for quark-flavour separation of GPDs, yet while an active experimental programme is underway on proton-DVCS, the neutron remains almost unprobed. Moreover, the neutron-DVCS beam-spin asymmetry is dominated by the GPD E , which features prominently in Ji's expression for the total angular momentum of the quarks. Its measurement therefore has potential to shed very important light on the as-yet unknown composition of nucleon spin.

We present a preliminary extraction of beam-spin and the previously unmeasured target-spin asymmetry in neutron-DVCS from an experiment using the Jefferson Laboratory 6 GeV electron beam, a deuterated ammonia target and the large-angle spectrometer CLAS. Additionally, the current upgrade of the Jefferson Lab accelerator to operate at 12 GeV and the complementary construction of CLAS12 detectors open a vast new kinematic region to experiment, in which the neutron-DVCS beam-spin asymmetry is particularly sensitive to the GPD E and through it to the quark total angular momentum. A dedicated experiment – involving the construction of a neutron detector for CLAS12 – is planned at 11 GeV.

Polarized parton distributions effects in global analysis of fragmentation functions

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In the hard scattering reactions, partons turn in to the colorless and non-perturbative hadronic bound state and hadrons are detected in the final state. In this hadronization process, it is necessary to have QCD predictions for cross sections and decay rates. We present new functional form of Pion and Kaon fragmentation functions using charged-hadron production data in electron-positron annihilation from LEP, SLAC, DESY and KEK and also we add semi-inclusive asymmetries data from HERMES to do a global analysis on fragmentation functions for the first time. Our results for asymmetries are in very good agreement with experimental data and other Models from DSSV [1] and LSS [2]. Also we compared the fragmentation functions in our model with the HKNS, AKK and DSS [3-5]. Finally we study the role of polarized PDFs and their effects in our analysis up to next to leading order.

1. D. de Florian, R. Sassot, M. Stratmann and W. Vogelsang, Phys. Rev. D 80 (2009) 034030.
2. E. Leader, A. V. Sidorov and D. B. Stamenov, Phys. Rev. D 82 (2010) 114018.
3. M. Hirai, S. Kumano, T. H. Nagai and K. Sudoh, Phys. Rev. D 75, 094009 (2007).
4. S. Albino, B.A. Kniehl, G. Kramer, Nuclear Physics B 803 (2008).
5. D. de Florian, R. Sassot, and M. Stratmann, Phys. Rev. D 75 (2007).

QCD Analysis of the Bjorken Sum Rule Revisited

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We present the expanded analysis of the polarized Bjorken (B_j) sum rule up to α_s^4 -order, which is based on the recent low Q^2 data from the Jefferson Lab and COMPASS collaboration experiments, and is continuation of our previous researches [1, 2]. We analyze values of higher-twist (HT) terms extracted from the mentioned data taking into account the renormalization group Q^2 -evolution of the twist-4 coefficient. We also consider the interplay between higher orders perturbative (PT) expansion and HT contribution. We discuss the model for QCD correction and show that the natural border between PT and non-PT regions is 1 GeV^2 . We found that results of our extended analysis of the B_j sum rule is in agreement with the previous result [2]. Thus, the main conclusions of Ref. [2] remain valid. Further, it is well-known that the QCD correction to the Gross-Llewellyn Smith (GLS) sum rule is similar to the B_j sum rule and available now up to 4-loop level [3]. Therefore, we perform a similar analysis at low Q^2 for the GLS sum rule. In the Table 1 we present fitted values of the HT coefficient μ_4 in different PT orders both for on the B_j and GLS sum rules.

Table 1: Results of HT extraction from data on the B_j and GLS sum rules.

PT order	$\mu_4^{B_j}, \text{ GeV}^2$	$\mu_4^{GLS}, \text{ GeV}^2$
LO	-0.050 ± 0.006	-0.33 ± 0.10
NLO	-0.030 ± 0.006	-0.009 ± 0.10
N ² LO	-0.013 ± 0.006	-0.04 ± 0.10
N ³ LO	0.009 ± 0.006	0.22 ± 0.10

In addition we compare extracted values of μ_4 with the assumption about the connection of HT contributions to the B_j and GLS sum rules (see Ref. [4] for more details). One can see that in the leading order (LO) our values of HT coefficients are consistent with $\mu_4^{GLS} = -0.29 \pm 0.15$ from Ref. [5] and $\mu_4^{B_j} = -0.047 \pm 0.025$ from Ref. [6].

References

1. R.S. Pasechnik, D.V. Shirkov, O.V. Teryaev, O. P. Solovtsova, and V. L. Khandramai, Phys. Rev. D 81 016010 (2010).
2. V. L. Khandramai, R.S. Pasechnik, D.V. Shirkov, O. P. Solovtsova, and O.V. Teryaev, Phys. Lett. B 764, 340 (2012).
3. P. A. Baikov, K.G. Chetyrkin, J. H. Kühn, and J. Rittenger, hep-ph/1206.1288.
4. A. L. Kataev, Mod. Phys. Lett. A 20, 2007 (2005).
5. V. M. Braun, A.V. Kolesnichenko, Nucl. Phys B 283, 723 (1987).
6. G.G. Ross, R.G. Roberts, Phys. Lett. B 332, 425 (1994).

Dual H&D Cavity for the PAX Target Polarimeter

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The former HERMES target polarimeter (BRP) [1] which is now part of the PAX polarized gas target set-up [2], employed two sets of rf-resonators, one for hydrogen, and one for deuterium operation. The frequency for two-level transitions ($\Delta F = +/-1$) is in the order of the hfs splitting energy ΔW at $B = 0$ which corresponds to 1421.4 MHz for hydrogen (H) and 327.4 MHz for deuterium (D).

The HERMES target has been operated in long periods for one target species only. In order to switch from H to D or vice versa, the resonating structures had to be exchanged, and a tedious tuning procedure had to be performed. Some of the Filtering Tests that can be possibly foreseen at the CERN AD would require to run the BRP subsequently with H and D with no time in between for modifications. Therefore a system of resonators is required which can run both on H or D frequencies without mechanical change-over. In addition, the magnetic component of the rf-field should be tilted by 45° with respect to the static field in order to allow both for σ and π transitions ($\Delta m_F = 0$ and ± 1 , resp.). If a single cavity can serve both H and D, the existing hardware could be used, like the static field magnets and the vacuum system. The development of such a "Dual Cavity" will be described in the contribution. Similar cavities based on "Tuned Twin Lines" have been used in Atomic Beam Sources (see e.g. [3]). Their principles of operation will be discussed as well.

References

1. C. Baumgarten *et al.*, Nucl. Instr. Meth. **A482**, 606, (2002).
2. G. Ciullo *et al.*, Proceed. Spin2010, Journal of Physics: Conf. Series **295** 012150 (2011).
3. E. Steffens, IEEE Trans. Nucl. Sci. **NS 23**, 1145 (1976).

Study of the $\gamma d \rightarrow pp\pi^-$ reaction in the photon energy region

(310 – 1200) MeV at the VEPP-3

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The reaction $\gamma d \rightarrow pp\pi^-$ has been measured on internal tensor-polarized deuterium target of VEPP-3 electron storage ring (electron energy 2 GeV) by detecting two protons (proton momentum ranges 310-700 MeV/c) in coincidence [1]. The energies and trajectories of protons were measured by two hadron hodoscopes. Each hodoscope consists of three plastic scintillator detectors and three multilayer drift chambers. Target polarization was measured by LQ-polarimeter and beam luminosity was determined out by elastic ed -scattering.

The experimental differential cross section of the negative pion photoproduction on deuteron is presented as a function of the proton momentum. The T21 tensor analyzing power component of the reaction was obtained as functions of the invariant mass for the pp -subsystem in the region of (1980-2220) MeV/c², $pp\pi^-$ -subsystem in the region of (1080-1700) MeV/c², $Mpp\pi^-$ -system in the region (2150-3100) MeV/c², and photon energy (310-1200) MeV. The experimental data were compared with the results of the calculations made within spectator model accounting NN and πN -rescattering effects with contribution of the background processes. Satisfactory agreement was obtained.

The mismatch between experimental and calculated behaviour of T21 tensor analyzing power component was found in both narrow and broad intervals of the kinematic variables.

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References

1. V.V. Stibunov *et al.*, Journal of Physics: Conference Series **295**, 012115 (2011).

DGLAP Evolution of the Truncated Moments of PDFs in Spin Physics

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We review evolution equations for truncated Mellin moments (TMM) of the parton densities. The main finding of the presented approach is that the n th truncated moment of the parton distribution obeys the DGLAP-like equation, with a rescaled splitting function $P'(z) = z^n P(z)$. This approach allows one to restrict the analysis to the experimentally available Bjorken- x region. We present some applications of TMM to study the spin structure functions of the nucleon.

References

1. D. Kotlorz and A. Kotlorz, Phys. Lett. **B644**, 284 (2007).
2. D. Kotlorz and A. Kotlorz, Acta Phys. Pol. **B39**, 1913 (2008).
3. D. Kotlorz and A. Kotlorz, Acta Phys. Pol. **B40**, 1661 (2009).
4. D. Kotlorz and A. Kotlorz, Acta Phys. Pol. **B42**, 1231 (2011).
5. S. Forte and L. Magnea, Phys. Lett. **B448**, 295 (1999).
6. S. Forte, L. Magnea, A. Piccione and G. Ridolfi, Nucl. Phys. **B594**, 46 (2001).
7. A. Piccione, Phys. Lett. **B518**, 207 (2001).
8. S. Forte, J. Latorre and L. Magnea Nucl. Phys. **B643**, 477 (2002).
9. A. Psaker, W. Melnitchouk, M.E. Christy and C. Keppel, Phys. Rev. **C78**, 025206 (2008).

Magnetic Resonance Spectroscopy of the Human Brain

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I give a brief description of the magnetic resonance spectroscopy (MRS) in the human brain examinations.

MRS allows a noninvasive chemical analysis of the brain using a standard high field MR system. Nowadays, the dominant form of MR brain spectroscopy is proton spectroscopy. Two main techniques of MRS, which utilize the chemical shift of metabolites in the external magnetic field, are SVS (single voxel) and CSI (single slice). The major peaks in the spectrum of a normal brain include NAA, Cr, Cho and m-Ins, which are neuronal, energetic, membrane turnover and glial markers, respectively. In disease, two pathological metabolites can be found in the brain spectra: Lac, which is end product of anaerobic glycolysis and Lip, which is a marker of membrane breakdown, occurring in necrosis. The common way to analyze clinical spectra is to determine metabolite ratios, e.g. NAA/Cr, Cho/Cr, Cho/NAA. This analysis permits a safe and noninvasive examination of the brain tissue as each disease state has its own characteristic spectroscopic image. MRS is a valuable diagnostic tool in such clinical applications as detecting brain tumors and differentiating tumors from inflammatory and infectious processes. Proton MRS is also very helpful in diagnostic of ischemic lesions, Alzheimer's disease and hepatic encephalopathy. The MRS brain spectra should always be correlated with the MRI results and alone cannot make neurological diagnosis.

References

1. D. Strozik-Kotlorz, *Proton Magnetic Resonance Spectroscopy of the Human Brain*, Ofic. Wydaw. PO, Studia i Monografie, (Opole, 2012) in print
2. E. Purcell, H. Torrey and R. Pound, Phys. Rev. **69**, 37 (1946).
3. F. Bloch, W. Hansen and M. Packard, Phys. Rev. **69**, 127 (1946).
4. P. Barker, J. Gillard and A. Waldman, *Fundamentals of MR Spectroscopy*, (Cambridge University Press, 2005) p. 7-26
5. D. Drost, W. Riddle and G. Clarke, Med. Phys. **29**, 2177 (2002).
6. V. Govindaraju, K. Young and A. Maudsley, NMR Biomed **13**, 129 (2000).
7. C. Majos et al., AJNR **25**, 1696 (2004).
8. S. Ramin, W. Tognola and A. Spotti, Sao Paulo Med J **121**(6), 254 (2003).
9. B. Ross and S. Bluml, The Anatomical Record (New Anat.) **265**, 54 (2001).
10. Z. Sajjad and S. Alam, Pak J Neurol Sci **2**(1), 42 (2007).
11. K. Harris and W. Wong, NeuroRx. **2**(2), 197 (2005).

Recent STAR results on the gluon polarization program in polarized $\bar{p} + \bar{p}$ collisions at RHIC

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The STAR experiment at the Relativistic Heavy-Ion Collider at Brookhaven National Laboratory is carrying out a spin physics program in high-energy polarized proton collisions at $\sqrt{s} = 200$ GeV and $\sqrt{s} = 500$ GeV to gain a deeper insight into the spin structure and dynamics of the proton.

One of the main objectives of the spin physics program at RHIC is the precise determination of the polarized gluon distribution function, Δg . Inclusive measurements, such as inclusive hadron and jet production, integrate over a fairly large x range for a given jet transverse momentum region. While those measurements provide a strong constraint on the value of Δg integrated over a range in x , they are not sensitive to the actual x dependence. This motivates the need for correlation measurements in polarized proton-proton collisions, such as di-jet production.

Recent STAR results will be shown on the measurement of inclusive hadron and jet production and di-jet production at $\sqrt{s} = 200$ GeV along with projections for future measurements in particular at $\sqrt{s} = 500$ GeV.

Improved Results on Transverse Double Spin Asymmetries in the CNI region at STAR

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At high energies and very small momentum transfer proton-proton elastic scattering is described by the interference of the Coulomb and nuclear amplitudes (CNI region). The latter is believed to be totally dominated by the classical pomeron exchange. In this case no double spin flip amplitude is present in the nuclear term and only very small double spin asymmetries can be expected due to the electromagnetic component. The manifestation of non-negligible transverse double spin effects would point to possible contributions from other Reggeons, such as the hypothetical Odderon, to the scattering amplitude.

Measurements of double spin asymmetries require external luminosity normalization using beam counts for all spin combinations. Several possible sources of such data from various STAR subsystems were thoroughly analyzed to make the best choice. The consistency of the two selected sources approaches the level of $\sim 10^{-3}$ providing sensitivity to the double spin effects at the scale of the same order of magnitude.

Improved results on the double spin asymmetries A_{NN} and A_{SS} based on the optimal choice of the normalization sources are presented. The data set of ~ 20 million elastic events in transversely polarized pp collisions at $\sqrt{s} = 200$ GeV was obtained by the STAR experiment at RHIC and is exactly the same as described in [1] for the single spin asymmetry measurements. The data covers $-t$ range $0.003 < -t < 0.035$ (GeV/c)².

References

1. L. Adamczyk *et al.* [STAR Collaboration], arXiv:1206.1928 [nucl-ex].

Target mass corrections for polarized structure functions

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In our previous analysis, we extracted parton distribution functions (PDFs) and structure functions from recent experimental data of polarized lepton-DIS on nucleons at next-to-leading order (NLO) Quantum Chromodynamics [1-3].

With recent advances in the precision of inclusive lepton-nuclear scattering experiments, it has become apparent that comparable improvements are needed in the accuracy of the theoretical analysis tools. In particular, when extracting parton distribution functions in the large- x region, it is crucial to correct the data for effects associated with the non-zero mass of the target [4-7]. We present here an updated, more accurate, version of our calculations on performing a global fit to the existing data by imposing target mass correction effects. The effects of these corrections are studied and polarized structure functions with and without them are compared.

References

1. A. N. Khorramian, S. Atashbar Tehrani, S. Taheri Monfared, F. Arbabifar and F. I. Olness, Phys. Rev. D **83**, 054017 (2011) [arXiv:1011.4873 [hep-ph]].
2. A. N. Khorramian, S. Atashbar Tehrani, F. Olness, S. Taheri Monfared and F. Arbabifar, Nucl. Phys. Proc. Suppl. **207-208**, 65 (2010).
3. S. Taheri Monfared, A. N. Khorramian, F. Arbabifar and S. Atashbar Tehrani, Acta Phys. Polon. B **41**, 2921 (2010).
4. Y. B. Dong, Phys. Lett. B **641**, 272 (2006).
5. J. Blumlein, B. Geyer and D. Robaschik, Nucl. Phys. B **755**, 112 (2006) [hep-ph/0605310].
6. J. Blumlein and A. Tkabladze, Nucl. Phys. B **553**, 427 (1999) [hep-ph/9812478].
7. E. Leader, A. V. Sidorov and D. B. Stamenov, Phys. Rev. D **80**, 054026 (2009) [arXiv:0908.2390 [hep-ph]].

Study of Nuclear Structure and Reaction by Using Polarized Proton Beams at RCNP

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At the Research Center for Nuclear Physics (RCNP), polarized proton beams are used for studying nuclear structure and reaction from low energy to 400 MeV. In this conference, I will report recent topics of such studies.

- 1) Inelastic scattering of polarized protons from ^{208}Pb have been measured at zero degrees and forward scattering angles at 295 MeV. Electric dipole (E1) transition strengths have been precisely determined over the excitation energies from 5 to 19 MeV. The data have been combined with other data up to 130 MeV to precisely determine the electric dipole polarizability, which is an inversely energy weighted sum-rule of the E1 transition strengths. The data are important to extract the parameters of the symmetry energy, especially the density dependence, of the nuclear equation of state (EoS) [1].
- 2) Elastic scattering cross section and analyzing power of protons from lead isotopes have been precisely measured at 295 MeV. The data have been analyzed in the framework of relativistic impulse approximation to extract the neutron density distribution of the target nuclei. By using the proton density distribution determined by electron scattering, the neutron skin thickness of ^{208}Pb has been determined as $0.211 \pm 0.054 \pm 0.063$ fm including the uncertainty of the model dependence. The data are also important to determine the symmetry energy parameters of the nuclear EoS [2].
- 3) Cross sections, analyzing powers, and a complete set of spin observables have been measured for the $^{208}\text{Pb}(p, n)$ reaction at forward angles and at 296 MeV. A multipole decomposition technique was applied to the data, including the spin observables, to extract the strength distributions of Gamow-Teller (GT) and each spin-dipole component from the continuum. The data are reproduced by a theoretical calculation using Hartree-Fock (HF) plus random phase approximation and the Skyrme interaction with tensor components [3].
- 4) Medium modification of the nucleon-nucleon (NN) interaction has been studied by measuring cross sections and analyzing powers of the (p, pn) reaction from ^6Li and ^{12}C targets at 392 MeV. The analysing powers are similar to the free-space NN reaction in neutron forward-scattering setting but are significantly small for proton forward-scattering setting. The result is not well explained by simple medium modification models [4].

References

1. A. Tamii *et al.*, Phys. Rev. Lett. **107**, 062502 (2011).
2. J. Zenihiro *et al.*, Phys. Rev. C **82**, 044611 (2010).
3. T. Wakasa *et al.*, Phys. Rev. C **85**, 064606 (2012)
4. R. Yamada, PhD thesis, Kyushu Univ. (2010).

Production of Hyperpolarized Nuclei for MRI

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Application of nuclear spin to biology and medicine started at the early seventies when the NMR spectroscopy was used for biomedical research [1], however, full-scale application of nuclear spins to this field only took off after the invention of MRI (Magnetic Resonance Imaging) [2,3] in 1973. In the mid nineties, it was demonstrated that substantially enhanced NMR signals could be obtained if nuclei pertinent to the NMR were hyperpolarized, i.e. more polarized than TE (thermal equilibrium) values, as exemplified by mouse lung images obtained by the ¹²⁹Xe - MRI in 1994 [4]. Since then, hyperpolarized MRI has been intensively developed for biomedical research, where the nuclei with a spin 1/2, such as ³He, ¹³C, ¹⁵N, and so on are hyperpolarized. Most methods employed to hyperpolarize these nuclei so far are laser optical pumping [4], dynamic nuclear polarization (DNP) [5], and para-hydrogen induced polarization (PHIP) [6]. Recently, we started hyperpolarizing ³He by the brute force method using low temperature and high magnetic field [7] aiming at productions of larger volumes of hyperpolarized ³He than ever before. A test experiment to generate hyperpolarized ¹⁹F in PFC (Perfluorocarbon) and FDG (Fluorodeoxyglucose) has got started for medical diagnosis of circulatory system and cancer. This report gives some of the results.

References

1. R. Damadian, *Science* **171** 1151 (1971).
2. P. C. Lauterbur, *Nature* **242** 190-191 (1973).
3. P. Mansfield, and PK. Grannell, *J Phys C: Solid State Phys.* **6** L422-L427 (1973).
4. M. S. Albert, G. D. Cates, Driehuys, W. Happer, B. Saam, C. S. Springer Jr, and A. Wishnia, *Nature* **370** 199 (1994).
5. J. H. Ardenkjær-Larsen, B. Fridlund, A. Gram, G. Hansson, L. Hansson, M. H. Lerche, R. Servin, M. Thaning, and K. Golman, *PNAS* **100** 10158 (2003).
6. K. Golman, O. Axelsson, H. Jóhansson, S. Månsson C. Olofsson, and J. S. Petersson, *Mag. Res. in Medicine* **46** 1 (2001).
7. M. Tanaka, T. Kunimatsu, T. Inomata, M. Fujiwara, H. Kohri, T. Ohta, M. Yosoi, K. Fukuda, K. Takamatsu, M. Utsuro, J. -P. Didelez, G. Frossati, and A. de Waard, *J. Phys.: Conference Series* **295** 012167 (2011)

Search of non-standard strong gravity at nuclear scale using electron spin Geodetic precession

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A modification of gravitational inverse square law at a microscopic scale, which leads a strong gravitational field at around nuclei, is predicted by a large extra-dimension model in order to explain the hierarchy problem [1]. Instead of performing a direct test of the inverse square law using a table-top experiment [2] or a collider search [3], present experiment aims to search non-zero gravitational spin precession of polarized electrons in a nuclear scattering experiment, which should be negligible in the Newton gravity.

The strong gravitational field can be detected as a large spin precession effect caused by the “Geodetic precession” predicted by the general relativity theory as a result of warped space-time around the nuclear-mass. In this experiment, longitudinally polarized electrons emitted from un-polarized nuclear beta decay, are scattered by Coulomb scattering. The initial longitudinal polarization is transferred into transverse polarization via electromagnetic Thomas precession and the possible Geodetic precession in the nuclear scattering process. We have utilized a Mott-polarimeter using multi-wire drift chamber for the MTV experiment at TRIUMF [4], testing the time reversal symmetry by searching non-zero transverse polarization of electrons emitted from polarized nuclear beta decay.

The first experiment which named “MTV-G (MTV-Gravity) experiment”, was performed using a strong ⁹⁰Sr source at TRIUMF in 2011. The transverse polarization of the scattered electrons was successfully measured by the MTV polarimeter as functions of the nuclear scattering angles. By comparing with the prediction from the Thomas precession, we have succeeded to set a new upper limit of the strong gravitational field at around 100fm scale for the first time. Details of the experiment and results, together with the physics motivation and principle are going to be presented at the conference.

References

1. N. Arkani-Hamed, S. Dimopoulos, G. Dvali, *Phys. Lett.* **B429**, 263 (1998).
2. M. Hata *et al.*, *J. Phys.* **CS189**, 012019 (2009).
3. ATLAS Collab. *Phys.Lett.* **B705**, 294 (2011).
4. J. Murata *et al.*, *J. Phys.* **CS312**, 101011 (2011): This Conference by Yumi Totsuka.

A New FPGA-based Trigger/DAQ system for the MTV experiment at TRIUMF

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The MTV experiment at TRIUMF [1] is aiming to search non-zero T -violation in nuclear beta decay by measuring electron transverse polarization, which is measured as left-right scattering asymmetry in Mott-scattering of the electrons by a thin metal foil. The trajectories of the scattering electrons are detected with a CDC (Cylindrical Drift Chamber), which was commissioned in 2011 as the next generation tracking detector after performing physics production run in 2010 using a planar drift chamber [2].

The CDC with 400 anode channels are used with 10^7 pps ^8Li beam implanted on a surface of a stopper set at the center position of the CDC. The emitted electrons from the stopper is backwardly scattered by a thin metal foil set outside of the effective volume of the CDC. Then, the incident tracks and the backward scattered tracks are detected by the CDC. The scattering angles of these “V-tracks” are the measurement of this experiment.

In order to achieve a high statistical precision, a high speed-triggering and DAQ system is required to execute the physics production using the CDC. In the triggering section, we have built an intelligent triggering system which can select the V-track events from the huge forward scattering events by performing online pattern recognition using CDC hitting pattern information. To achieve the requirement, a new FPGA-based system including both the triggering and DAQ part in a single FPGA chip is developed. The DAQ part can obtain the TDC information in order to select the real hit signal from accidental hits in the high counting rate environment. We have confirmed about 500kHz triggering rate can be handle with this new triggering-DAQ combined system.

The development status and technical details will be presented in this conference.

References

1. J. Murata *et al.*, J. Phys. CS312, 101011 (2011): This Conference by Yumi Totsuka.
2. J. Onishi *et al.*, J. Phys. CS312, 101012 (2011)

Can gluon spin contribute to that of nucleon?

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The contribution of quark spin (described by the totally antisymmetric angular momentum tensor) to the angular momentum of nucleon (proportional to Belinfante symmetric energy-momentum tensor) is possible due to the relocalization (Belinfante) invariance. It requires the fast enough decrease of the quark fields at the spatial infinity which corresponds [1] to the smooth behavior of the matrix elements of singlet quark axial current at zero momentum transfer. The latter provides the kinematical counterpart of famous $U_A(1)$ problem.

For the case of gluons, which is completely analogous but was not considered in such a context before, the appearance of totally antisymmetric contribution proportional to the topological gluon current (in the axial gauge) requires the similar smooth behavior of its matrix element. However, the same $U_A(1)$ problem implies [2] the appearance of the pole in its matrix element. One may expect the 3 possible outcomes from this controversy.

- Romantic: The gluon spin contributes to the spin of nucleon but the pole indeed spoils the transition from the conserved total angular momentum to its Belinfante form. As the Belinfante energy momentum tensor describes the coupling to gravity, establishing its link with non-perturbative QCD, this should result in the violation of the Post-Newtonian Equivalence Principle (directly related to the conservation laws) at least on the percent level which can be measurable, say, in the next generation of EDM experiments. Needless to say, that Ji's sum rules for Generalized Parton Distributions could be also violated at the same level.
- Restrictive: The topological current matrix element, which can have the massless (Kogut-Susskind) pole in reality does not have it. This, however, should lead to the zero matrix element of conserved quark gluon current in the chiral limit. Taking into account the smallness of gluon contribution, the observed (singlet)

quark polarization should be related to (strange) quark mass, which does not look plausible but may be studied further, bearing in mind the possibility to consider the strange quark as a heavy one.

- Trivial: The Total angular momentum of gluon should not be decomposed to spin and orbital parts and the angular momentum conservation should be presented in terms of Belinfante tensor only.

References

1. O.V. Teryaev, [hep-ph/9303228](#), [hep-ph/0612205](#).
2. A.V. Efremov, J. Soffer and O.V. Teryaev, Nucl. Phys. **B346**, 97 (1990).

The new Frozen Spin Target at MAMI

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A Frozen Spin Target offers the opportunity to use longitudinally and transversely polarized nuclei (protons, deuterons, ${}^6\text{Li}$, ...) with a high degree of polarization and, due to the solid state of the target material, a high density in the order of 10^{23} nuclei/cm². The thermal input from the beam has to be limited, since low temperatures generate long spin relaxation times, which are essential for experiments with long duration in the order of weeks.

The A2-collaboration at the Mainz Microtron MAMI is measuring photon absorption cross section using circularly and linearly polarized photons up to energies of 1.5GeV. The photons are produced in the 'Bremsstrahlungs' process, the energy is determined by a dedicated tagging system. In the years 2005/2006 the Crystal Ball detector with its unique capability to cope with multi photon final states was set up in Mainz.

Since 2010 the experimental apparatus has been completed by a polarized target. The horizontal dilution refrigerator of the Frozen-Spin Target has been constructed and is operated in close cooperation with the Joint Institute for Nuclear Research in Dubna, Russia. The system includes a longitudinal or transverse superconducting coil to allow for all directions of polarization.

In this talk the operation experience of this new Frozen-Spin Target and first results from the runs in 2010 and 2011 will be presented.

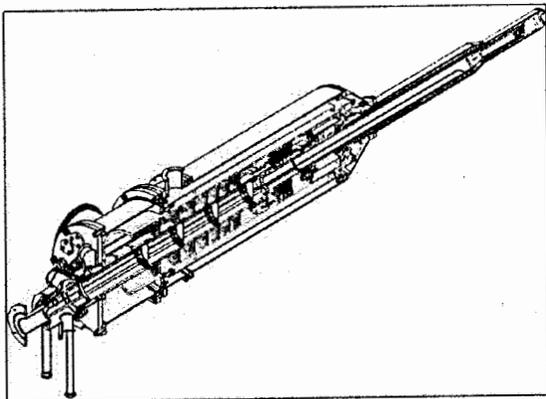


Figure 1. The new dilution refrigerator, constructed and produced in Dubna.

A complete polarized low-energy proton-deuteron breakup experiment

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With the introduction of chiral effective field theory as a fundamental means to approach the strong force at low to intermediate energy [1] and the development that followed [2], a formulation of hadron physics from first principles has been established providing a solid theoretical framework for the interpretation of data in the few-nucleon sector. The nature of three-nucleon interaction effects remains unclear in spite of large experimental and theoretical efforts. Comparisons of the data and the theoretical predictions of the so called high-precision nucleon-nucleon potentials in conjunction with traditional three-nucleon force models show contradictory results when varying the particular observable and the part of phase space chosen to be studied [3]. Complete and precise experimental data is required to provide conclusive statements and to test the predictive power of chiral effective theory. In compliance with this we are planning a double polarized experiment at COSY using a polarized proton beam at 50 MeV and a vector and tensor polarized target fed by an atomic beam source [4]. The 7 analyzing powers and 15 spin correlation coefficients possible in proton deuteron breakup will be accessible with large acceptance using the new PAX facility. The precision capacity of our experimental setup was recently shown to be of the order of 10^{-3} for a measurement of the asymmetry [5]. We have made sensitivity studies of the spin observables on pre-calculated theoretical grids at next-to-next-to-leading order using the so called *sampling method* [6] that takes into account the true experimental acceptance and efficiency¹.

References

1. S. Weinberg, Phys. Lett. B **251**, 288 (1990); Nucl. Phys. B **363**, 3 (1991).
2. E. Epelbaum and Ulf-G. Meißner, Commissioned article for Ann. Rev. of Nucl. and Part. Sci., arXiv:1201.2136v1, and references therein.
3. N Kalantar-Nayestanaki, E Epelbaum, J G Messchendorp and A Nogga, Rep. Prog. Phys. **75** (2012) 016301 (41pp), and references therein.
4. P. Thörngren Engblom et al., Proposal no. 202.1 submitted to the COSY Program Advisory Committee by the PAX Collaboration. available at www2.fz-juelich.de/ikp/publications/PAC39/PAX_proposal202.1_202.pdf.
5. P. Lenisa and F. Rathmann for the PAX Collaboration, available at cdsweb.cern.ch/record/1433777/files/SPSC-SR-099.pdf.
6. J. Kuroś-Zolnierczuk, P. Thörngren Engblom, H.-O. Meyer, T. J. Whitaker, H. Witala, J. Golak, H. Kamada, A. Nogga, and R. Skibiński, Few-Body Systems **34**, 259273 (2004).

¹The theoretical calculations are provided by A. Nogga

First Result from the MTV experiment at TRIUMF searching T-Violation in nuclear beta decay

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It is widely believed that there must be large $CP(T)$ -violating phenomena outside of the CKM mechanism, because the amount of CP -violation predicted by the CKM is insufficient to explain the observed large matter-antimatter asymmetry in our universe. The MTV (Mott Polarimetry for T-Violation Experiment) experiment at TRIUMF aims to perform the highest precision test of time reversal symmetry in polarized nuclear beta decay by measuring a triple vector correlation, defined as R -correlation in $\omega dE_e d\Omega_e \propto \dots N \vec{\sigma} \cdot \langle \vec{J} \rangle + R \vec{\sigma} \cdot \langle \vec{J} \rangle \times \frac{p_e}{E_e}$, motivating to search a new physics beyond the Standard Model [1].

Observation of a non-zero value of the R -parameter implies existence of T -violating transverse electron polarization perpendicular to the parent nuclear polarization direction. The electron transverse polarization in the vertical direction can be extracted from the measured value of the backward scattering left-right asymmetry in Mott scattering by a thin metal foil [2]. In the MTV experiment, a planar drift-chamber is used to track both initial electron tracks and backward scattering tracks (V-tracks). The Mott scattering angle is determined by this tracking information in event by event.

The first commissioning experiment (Run-I) was performed at TRIUMF in 2009 using an 80% polarized ^8Li beam at 10Mpps after confirming the detector performances at KEK-TRIAC [3], and the physics production run (Run-II) was performed in 2010. The result from the offline analysis is obtained with a statistical precision of about 0.1%. Summarized results from the Run-II including the systematic error studies are going to be presented in this conference. We have already started the next generation experiment using CDC (Cylindrical Drift Chamber), mainly aiming to suppress the systematic effects which dominates on the Run-II experiment because of the asymmetric geometry of the planar drift chamber. Preliminary results of the experiment using the CDC will also be presented.

References

1. J.D. Jackson et al., Nucl.Phys.A4, 206-212(1957), Phys.Rev.106, 517-52(1957)
2. J. Murata et al., J. Phys. CS312, 102011(2011)
3. H. Kawamura, D.Sc Thesis, Rikkyo University(2009)

NEDM Experiment at SNS

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NEDM collaboration proposes to measure Neutron Electric Dipole Moment at the Spallation Neutron Source (Oak Ridge National Laboratory). NEDM is a clear signature of the CP violation. According to the Standard Model NEDM is very small ($\sim 10^{-31} e \cdot \text{cm}$), but many theories expect much higher value.

In the proposed experiment polarized cold neutrons from SNS are trapped in liquid helium at the temperature of about 300 mK. Neutron spin precesses in very uniform magnetic field $H \sim 30$ mG, and the experiment measures the change in the precession frequency when very strong electric field $E \sim 50$ kV/cm is applied. Polarized ^3He atoms serve as a comagnetometer. The goal of the experiment is to measure NEDM with an accuracy of $\sim 9 \cdot 10^{-28} e \cdot \text{cm}$, which is two orders of magnitude better than existing results.

Measurement of the differential cross section and vector analysing power of the $\bar{p}p \rightarrow \{pp\}_s \pi^0$ reaction at 353-700 MeV

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The reaction $\bar{p}p \rightarrow \{pp\}_s \pi^0$ has been observed with the ANKE spectrometer at COSY-Jülich [1] using a polarized beam with energies 353, 500, 550 and 700 MeV. The proton pair $\{pp\}_s$ is detected at low excitation energy $E_{pp} < 3$ MeV, where S -wave dominates. The data have been processed to obtain the vector analysing power A_y and differential cross section $d\sigma/d\Omega$ of the reaction. The setup acceptance covers most of the angular range at 353 MeV and forward angles at the higher beam energies, allowing one to obtain corresponding A_y and $d\sigma/d\Omega$ angular dependences.

From the results of the analysis at 353 MeV, one can extract information on the pion s - and d -wave contributions and, by using the phase information from elastic pp scattering, unique solutions can be obtained for the corresponding amplitudes [2]. This information is important for Chiral Perturbation Theory tests at this energy [3].

At higher energies the cross section at 0° is found by extrapolating $d\sigma/d\Omega$ angular dependence, allowing to detailize the energy dependence of $d\sigma/d\Omega(0^\circ)$ obtained earlier [4]. The measured cross sections and analysing powers are compared with phenomenological models [5,6].

References

1. S. Barsov *et al.*, Nucl. Instrum. Methods Phys. Res. A **462**, 354 (2001).
2. D. Tsirkov *et al.*, Phys. Lett. B **712**, 370 (2012).
3. V. Baru *et al.*, Phys. Rev. C **80**, 044003 (2009).
4. V. Kurbatov *et al.*, Phys. Lett. B **661**, 22 (2008).
5. Yu. Uzikov, Proc. XIX Int. Baldin Seminar HEPP, eds. A. Sissakian *et al.*, (Dubna, 2008) v. 2, p. 307.
6. J.A. Niskanen, Phys. Lett. B **642**, 34 (2006).

Unique R -parity violating sneutrino exchange signatures at e^+e^- linear colliders with polarized beams

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Numerous non-standard dynamics are described by contact-like effective interactions that can manifest themselves in electron-positron collisions only through deviations of the observables (cross sections, asymmetries) from the Standard Model predictions. If such a deviation were observed, it would be important to identify the actual source among the possible non-standard interactions as many different new physics scenarios may lead to very similar experimental signatures. We study the possibility of uniquely identifying the indirect effects of s -channel sneutrino exchange, as predicted by supersymmetric theories with R -parity violation, against other new physics scenarios in high-energy e^+e^- annihilation into lepton pairs at a linear collider (LC). These competitive models are interactions based on gravity in large and in TeV-scale extra dimensions, anomalous gauge couplings, Z' vector bosons and compositeness-inspired four-fermion contact interactions. To evaluate the identification reach on sneutrino exchange, we use as basic observable a double polarization asymmetry, that is particularly suitable to directly test for such s -channel sneutrino exchange effects in the data analysis. The availability of both beams being polarized plays a crucial rôle in identifying the new physics scenario. The identification reach obtained at LC is compared with those derived in Drell-Yan process at the LHC [1,2].

References

1. P. Osland *et al.*, Phys. Rev. D **82**, 115017 (2010).
2. N. Paver *et al.*, J. Phys. Conf. Ser. **295**, 012074 (2011).

Precise Polarization Measurements via Electron Detector For QWEAK Experiment

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The QWEAK experiment at Jefferson Lab aims to make a 4% measurement of the parity-violating asymmetry in elastic scattering at very low Q^2 of a longitudinally polarized electron beam on a proton target. One of the dominant experimental systematic uncertainties in QWEAK will result from corrections due to beam polarization.

A new Compton polarimeter was installed in fall 2010 for a non-invasive and continuous monitoring of the electron beam polarization in Hall C at Jefferson Lab. The Compton-scattered electrons are detected in four planes of diamond micro-strip detectors. This polarimeter has been used for online monitoring of beam polarization in the experiment. We have achieved the design goals of $\leq 1\%$ statistical uncertainty per hour and expect to achieve 1% systematic uncertainty.

This talk will outline setup, the analysis approach and the preliminary results.

Spin-dependence of the interaction of antiprotons with the lightest nuclei

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The scattering of antiprotons off a polarized ^1H [1], ^2H [2] or ^3He [3] target in rings can be used for antiproton polarization buildup as proposed by the PAX collaboration [4] at the future FAIR facility. In addition, $\bar{p}d$ and $\bar{p}^3\text{He}$ scattering are interesting for studying the spin dependence of the elementary $\bar{p}N$ amplitudes. Spin-dependent total $\bar{p}d$ cross sections at 20-300 MeV beam energies were considered in Ref. [2] using the optical theorem. For this aim the full spin dependence of the forward amplitude of $\bar{p}d$ elastic scattering was derived. To relate this amplitude to elementary amplitudes of $\bar{p}p$ and $\bar{p}n$ elastic scattering and to the deuteron form factor, a single scattering approximation was used. Numerical calculations for the polarized total cross sections were performed at beam energies of 10-200 MeV, employing the Jülich model of the NN interaction [5]. Double scattering effects in unpolarized cross section are estimated within the Glauber model and found to be 15-20%. In the present work double scattering effects are taken into account also in the calculation of spin observables using, in part, the formalism developed for pd elastic scattering in Ref. [6]. Coulomb-nuclear interference effects are taken into account. It is found that the Glauber approximation works reliably for $\bar{p}d$ scattering even at rather low beam energies such as ~ 50 MeV. The calculated unpolarized cross sections are almost insensitive to the employed models of the NN interaction, whereas the predictions for polarized cross sections vary considerably for different models. This could allow one to discriminate between different NN models once data on $\bar{p}d \rightarrow \bar{p}d$ will appear [7]. The spin-dependent cross sections of the $\bar{p}^3\text{He}$ reaction are calculated on the basis of an approach similar to that developed in Ref. [3]. The $\bar{p}n$ amplitudes are expected to dominate the spin observables of this reaction. The validity of the Glauber approximation at low energies is tested by calculation of the $\bar{p}^4\text{He}$ differential cross section, and good agreement is found with data available at 20 MeV and 179 MeV.

References

1. F. Rathmann *et al.*, Phys. Rev. Lett. **94**, 014801 (2005).
2. Yu.N. Uzikov and J.Haidenbauer, Phys. Rev. **C79**, 024617 (2009).
3. Yu.N. Uzikov, J. Haidenbauer, B.A. Prmantaeva, Phys. Rev. **C84**, 054011 (2011).
4. V. Barone *et al.* [PAX Collaboration], arXiv:hep-ex/0505054.
5. T. Hippchen *et al.*, Phys. Rev. **C44**, 1323 (1991).
6. M.N. Platonova, V.I. Kukulkin, Phys. Rev. **C81**, 014004 (2010).
7. C. Barschel *et al.* [PAX Collaboration], arXiv:0904.2325[nucl-ex].

Searches for Physics beyond the Standard Model

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The Thomas Jefferson National Accelerator Facility has the demonstrated ability to test the fundamental symmetries of nature to very great precision and thereby probe for new physics beyond the Standard Model. Objectives and descriptions will be given of two Jefferson Laboratory (JLab) experiments: Qweak and MOLLER. The Qweak experiment is to measure the weak charge of the proton (via the vector coupling of the Z^0 boson to the proton). The MOLLER experiment is to measure the weak charge of the electron. These two experiments follow from the advances made in precision parity-violating electron scattering experiments at CEBAF of JLab. The Standard Model makes accurate predictions of the 'running' of the electroweak mixing angle or $\sin^2(\theta_w)$ from the Z^0 pole down to low energies and therefore of the weak charge of the proton and of the electron. The Qweak experiment is making the first precision determination of the weak charge of the proton, $Q_w^p = 1 - 4\sin^2(\theta_w)$, from a measurement of the parity-violating analyzing power in the scattering of longitudinally polarized electrons from the protons in a liquid hydrogen target at a very low momentum transfer of $Q^2 = 0.260 \text{ (GeV/c)}^2$ and an energy of 1.16 GeV. The projected result will determine the proton's weak charge with a 4.1% total error and consequently $\sin^2(\theta_w)$ with a 0.3% error. The Qweak experiment has at present completed the first phase of data taking with data analysis essentially finished. The second phase of data taking is scheduled to be completed early summer 2012. The MOLLER experiment is to measure the parity-violating analyzing power in the scattering of 11 GeV longitudinally polarized electrons from the atomic electrons in a liquid hydrogen target. The longitudinal analyzing power A_z is predicted to be 35.6 ppb at the kinematics of the experiment and is to be determined with a precision of 0.73 ppb, which would make the MOLLER experiment the most precise parity-violating scattering ever undertaken. The result would yield a measurement of the weak charge of the electron to 2.3% at an average Q^2 value of 0.0056 (GeV/c)^2 and in turn a determination of the electroweak mixing angle or $\sin^2(\theta_w)$ with an uncertainty of $\pm 0.00026 \text{ (stat)} \pm 0.00013 \text{ (syst)}$, comparable to the accuracy obtained in the two best determinations at the Z^0 pole. Other electroweak tests will be commented on.

Spinor gravity on lattice

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The spinor gravity is formulated in terms of fundamental fermion and gauge fields, the same type of degrees of freedom as in the Standard Model [1-2]. The theory is explicitly invariant under local Lorentz transformations and under diffeomorphisms. The theory is suitable for describing large nonperturbative and fast-varying fluctuations of metrics. We construct the lattice-regularized version of the spinor gravity, which support the gauge invariance, as well as, lattice-diffeomorphism invariance.

The lattice spinor gravity is the theory of a new type, the standard lattice method can not be applied directly. In many aspect the considered theory is alike models of the loop quantum gravity. The fermion background of the model allows us to avoid some problems usual for the standard theories, such as the problem of ultra-locality, absence of continuum limit, etc. As a price, the constructed theory is very involved and some of the geometrical observables can not be obtained on the fundamental level.

The lattice regularization allows us to calculate some classical geometric properties such as the total volume of the space, the susceptibility of volume distribution, average curvature and some others. Although the fluctuating curved space turns out to be on the average flat and smooth owing to the non-compressibility of the fundamental fermions, the low-energy Einstein limit is not automatic: one needs to ensure that composite metrics fluctuations propagate to long distances as compared to lattice spacing. One way to guarantee this is to stay at a phase transition point.

We develop a lattice mean field method and find that the theory typically has several phases in the space of the dimensionless coupling constants, separated by surfaces with a 2nd order phase transition. For example, there is a phase with a spontaneous breaking of chiral symmetry. The effective low-energy Lagrangian for the ensuing Goldstone field is explicitly diffeomorphism-invariant. We expect that the Einstein gravitation is achieved at a 2nd order phase transition surface in the space of the coupling constants.

References

1. D. Diakonov, arXiv:1109.0091 [hep-th].
2. C. Wetterich, arXiv:1108.1313 [hep-th].

HDice, the Polarized Solid HD Target in the Frozen Spin Mode for Experiments with CLAS

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Frozen-spin HD (Deuterium-Hydride) targets have been used with the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab during the E06-101 experiment. Both H and D were polarized at low temperatures ($\sim 10\text{mK}$) inside a vertical dilution refrigerator (Oxford Kelvinox-1000) at 15 Tesla field. The targets reached a frozen-spin state within a few months, after which they were cold transferred (2 K, 0.1 T) to a Storage cryostat (1.7 K, 4.5 T) during the 1 Km transport to the experimental Hall-B. Once in the Hall, the target was loaded into an In-Beam Cryostat (IBC), a thin-walled dilution refrigerator operating both vertically (for target transfers) and horizontally (for experimental running). The IBC held the HD target at 50 mK in an open geometry with minimal energy loss for exiting reaction products and target spins were oriented longitudinally with an 0.9 T solenoid. Photon fluxes up to 10^8 Hz were used and spin relaxation times (T_1) during the experiment were several years for both H and D. RF transitions were used to periodically flip the H polarization and to transfer the polarizations between H and D. A transverse saddle coil within the IBC was used with the solenoid to rotate D spins. The performance of the system and preliminary results will be discussed.

An Overview of Recent DVCS Results at HERMES

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The theoretical framework of Generalized Parton Distributions (GPDs) includes information on the correlated transverse spatial and longitudinal momentum distributions of partons in the nucleon. Furthermore, GPDs may provide a way to investigate the contribution of quark orbital angular momentum to the spin of the nucleon. Among other exclusive processes, hard exclusive leptonproduction of real photons, Deeply Virtual Compton Scattering (DVCS), is one of the theoretically cleanest ways to access GPDs. The HERMES experiment at DESY, Hamburg, collected unique data on DVCS utilizing the HERA polarized electron or positron beams with an energy of 27.6 GeV and longitudinally and transversely polarized or unpolarized gas targets (H, D or heavier nuclei). The azimuthal asymmetries measured in the DVCS process allow access to the imaginary and/or real part of certain combinations of GPDs. For the last two years of HERA running, the HERMES collaboration installed a recoil detector to improve the selection of DVCS events by direct measurement of the recoil protons. An overview of recent HERMES results on DVCS is presented including first results on DVCS and associated processes $ep \rightarrow e\gamma p\pi^0$ and $ep \rightarrow e\gamma n\pi^+$ in the Δ resonance region obtained with the recoil detector.

Search for Z^* boson at ATLAS detector

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The experimental consequences of the Standard Model extension by introducing new spin-1 chiral Z^* boson ([1, 2] and refs therein) are discussed.

The results of the search for new resonance produced by Z^* boson in channel with lepton and antilepton in the final state at ATLAS experiment are presented. The analyses includes $5.0/4.9 \text{ fb}^{-1}$ of data recorded by ATLAS detector during 2011 LHC 7TeV proton-proton run in dimuon/dielectron channel. Since a good agreement is observed between experimental data and Monte Carlo simulated Standard Model prediction – the masses of Z^* below 2.20TeV are excluded with Confidence Level of 95%.

Due to unique experimental Z^* signature consisting in angular distribution of it's decay products, a new selection criterion – a cut on pseudorapidity difference between final leptons $|\eta_1 - \eta_2| > 0.9$ – is proposed for 2012 data analysis. With respect to the plans of recording $\sim 15 \text{ fb}^{-1}$ of data by ATLAS detector in 2012, it will allow to implement search for new resonance up to masses $\sim 2.5\text{-}2.6 \text{ TeV}$.

References

1. M. Chizhov, V. Bednyakov and J. Budagov, *Phys. Atom. Nucl.* **71**, 2096 (2008).
2. M.V. Chizhov *et al.*, *Physics of Particles and Nuclei*, **43**, No. 3, 311 (2012).

Hadron Physics at LEPS and LEPS2

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The Laser-Electron-Photon facility at SPring-8 (LEPS) is a unique and very successful facility with the cleanest photon beam in the world at multi-GeV energies. The photon beam produced by means of laser-induced backward Compton scattering (BCS) from 8 GeV electrons has rather flat energy distribution with small spreading angles, unlike the Bremsstrahlung beam which has huge low-energy photons. The beam polarization is also high and nearly 100% at the maximum energy. Polarization observables play an important role to elucidate the photo-production mechanism. The LEPS experiments have been carried out since 2000 mainly using the forward charged-particle spectrometer to search for the pentaquark, and to study the ϕ -meson production, hyperon photoproduction, etc. We will present some recent results of the LEPS experiments.

A new project to construct the second beamline at SPring-8 (LEPS2) has just started. The LEPS2 improves the intensity of the photon beam and expands the detector acceptance by adopting a large solenoid magnet, which was originally used in BNL-E949 experiment. We will also present the brief view of the LEPS2 system and the current status of its construction.

The methods for computational modeling of magnets for experimental setups

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The design, construction and operation of magnetic systems of experimental setups require preliminary mathematical modeling.

While calculating the fields of the magnetic systems, we attempted to solve the inverse problem of magnetostatics, namely, to find an optimal construction of the current elements and ferromagnetic yoke for a required distribution of the magnetic field.

In this paper discusses the results of numerical modeling of the magnet field distribution for some modifications of the SP-94 spectrometric magnet used in some experimental setups for polarized experiments.

The quark intrinsic motion in a covariant approach

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We study the kinematics of deep inelastic scattering corresponding to the rotationally symmetric distribution of quark momenta in the nucleon rest frame. It is shown that rotational-symmetry together with Lorentz invariance can in leading order impose constraints on the quark intrinsic momenta. Obtained constraints are discussed and compared with the available experimental data. The important details can be found in [1] and citations therein.

References

I. P. Zavada, Phys.Rev. D **85** (2012) 037501.

Longitudinal spin structure of the nucleon at COMPASS

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Inclusive ($A_{1,p(d)}$) and semi-inclusive ($A_{1,p(d)}^{\pi^+}$, $A_{1,p(d)}^{\pi^-}$, $A_{1,p(d)}^{K^+}$ and $A_{1,p(d)}^{K^-}$) double-spin asymmetries in deep-inelastic muon-proton (muon-deuteron) scattering have been measured at COMPASS (SPS CERN) [1,2]. The results have been obtained with data collected in 2002-2004 and 2006 for the longitudinal polarised ^6LiD solid target and in 2007 for the longitudinal polarised NH_3 solid target. Beam of positive muons with energy $E = 160$ GeV have been used.

We improved the statistical precision of $g_1^p(x; Q^2)$ by a factor of two in the low x region. Proton asymmetries have been combined with the deuteron ones to extract the non-singlet spin-dependent structure function $g_1^{NS}(x; Q^2)$. The first moment Γ_1^{NS} confirms the validity of the Bjorken sum-rule [3]. Our semi-inclusive data were used to evaluate the Δu , Δd , $\Delta \bar{u}$, $\Delta \bar{d}$ and $\Delta s \equiv \Delta \bar{s}$ distributions [2].

New COMPASS data on longitudinal polarized NH_3 target were collected during the year 2011 with beam of positive muons with energy $E = 200$ GeV. It allows us to cover low x region up to 0.025.

References

1. M.Alekseev, et al. [COMPASS Collaboration], Phys. Lett. **B680**, 217 (2009).
2. M.Alekseev, et al. [COMPASS Collaboration], Phys. Lett. **B693**, 227 (2010).
3. M.Alekseev, et al. [COMPASS Collaboration], Phys. Lett. **B690**, 466 (2010).

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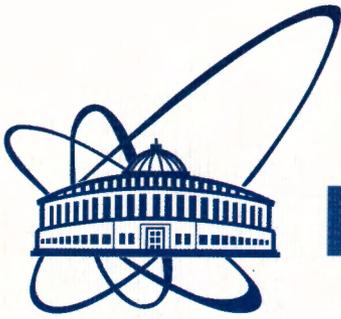
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