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Book of Abstracts

06 – Hadron Structure

Foreword

In the present booklet we have collected the one-page abstracts of all contributions (invited, oral and poster) accepted at the INPC2013 Conference in the topic

Hadron Structure

The submitted abstracts have been divided into the various topics of the Conference following mostly the indication given by the authors. In few cases, where the subject was on the borderline of two scientific areas or it appeared misplaced, the abstracts have been moved to the booklet of the more appropriate topic.

The abstracts are numbered and arranged alphabetically according to the name of the first author. In the parallel and poster sessions of the Conference, each contribution will be identified by the number of the corresponding abstract.

We wish you a pleasant and stimulating Conference.

The Organizing Committee

Hadron Structure (HS)

HS 001	Exclusive c to s, d semileptonic decays of ground-state spin-1/2 and spin-3/2 doubly heavy cb baryons *C. Albertus, E. Hernandez, J. Nieves* Contact email: *albertus@ugr.es*
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HS 004	Two-photon exchange contribution in elastic electron-proton scattering, experiment at the VEPP-3 storage ring *J. Arrington, L.M. Barkov, V.F. Dmitriev, V.V. Gauzshtein, R.A. Golovin, A.V. Gramolin, R.J. Holt, V.V. Kaminsky, B.A. Lazarenko, S.I. Mishnev, N.Yu. Muchnoi, V.V. Neufeld, D.M. Nikolenko, I.A. Rachek, R.Sh. Sadykov, Yu.V. Shestakov, V.N. Stibunov, D.K.Toporkov, H. deVries, S.A. Zevakov, and V.N. Zhilich* Contact email: *D.M.Nikolenko@inp.nsk.su*
HS 005	Search for higher lying charmonium and exotics in experiments using high quality antiproton beam with momentum up to 15 GeV/c *M. Barabanov, A. Vodopyanov* Contact email: *barabanov@jinr.ru*
HS 006	Spin alignment and OZI violation in exclusive ϕ and ω production in pp collisions at COMPASS *Johannes Bernhard* Contact email: *johannes.bernhard@cern.ch*
HS 007	Dalitz plot analysis for $\eta \rightarrow \pi^+\pi^-\pi^0$ at KLOE *Li Caldeira Balkeståhl* Contact email: *li.caldeira balkestahl@physics.uu.se*
HS 008	Chiral Structure of Light Scalar Mesons and Scalar Tetraquarks Currents *Hua-Xing Chen* Contact email: *hxchen@buaa.edu.cn*

HS 009	First measurement of the helicity dependence of ^{3}He photo-reactions in the Δ(1232) resonance region *S. Costanza* Contact email: *susanna.costanza@pv.infn.it*
HS 010	Neutron transverse-spin distributions onto the Light-front plane and the polarized ^{3}He target *A. Del Dotto, E. Pace, G. Salmè, S. Scopetta and E. Cisbani* Contact email: *alessio.deldotto@iss.infn.it*
HS 011	Gluon polarization and jet production at STAR *P. Djawotho* Contact e-mail: *pibero@tamu.edu*
HS 012	Study of the proton structure by measurements of polarization transfers inWide Angle Real Compton scattering at JLab *C. Fanelli, E. Cisbani, D. Hamilton, B. Wojtsekhowski* Contact email: *cristiano.fanelli@iss.infn.it*
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HS 014	Strangeness content of the proton in the unquenched quark model *J. Ferretti, R. Bijker, E. Santopinto* Contact email: *ferretti@ge.infn.it*
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HS 016	Charmonia and bottomonia hybrid predictions *G. Galatà, P. Guo, E. Santopinto, A. Szczepaniak, A. Vassallo* Contact email: *giuseppe.galata@nucleares.unam.mx*
HS 017	Nucleon structure through Generalized Parton Distributions *F.-X. Girod* Contact email: *fxgirod@jlab.org*
HS 018	Chiral Dynamics and Transverse Peripheral Densities *C. Granados, C. Weiss* Contact email: *carlosg@jlab.org*

HS 019	High-Accuracy Analysis of Compton Scattering in Chiral EFT: Status and Future *Harald W. Grießhammer* Contact email: *hgrie@gwu.edu*
HS 020	Generalized Parton Distributions: a general unifying tool for exploring the internal structure of hadrons *M. Guidal* Contact email: *guidal@ipno.in2p3.fr*
HS 021	Transverse target single-spin asymmetry in inclusive electroproduction of charged pions and kaons *Hermes Collaboration* Contact email: *management@hermes.desy.de*
HS 022	Comparative study of nonperturbative charm in the nucleon *T. J. Hobbs, J. T. Londergan, W. Melnitchouk* Contact email: *timjhobb@indiana.edu*
HS 023	Production of doubly charmed tetraquarks with exotic color configurations in electron-positron collisions *Tetsuo Hyodo, Yan-Rui Liu, Makoto Oka, Kazutaka Sudoh, Shigehiro Yasui* Contact email: *hyodo@th.phys.titech.ac.jp*
HS 024	Fragmentation and quark distribution functions for the pion and kaon with explicit flavor-SU(3)-symmetry breaking *Chung Wen Kao, Seung-il Nam* Contact email: *cwkao@cycu.edu.tw*
HS 025	Probing two-photon exchange with OLYMPUS *M. Kohl* Contact email: *kohlm@jlab.org*
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HS 029	Longitudinal and transverse spin structure of the nucleon at COMPASS *C. Marchand* Contact email: *claude.marchand@cea.fr*
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HS 031	Transverse spin and transverse momentum structure of the nucleon from the COMPASS experiment *Federica Sozzi* Contact email: *federica.sozzi@ts.infn.it*
HS 032	Monte Carlo Approach to Fragmentation Functions Using the NJL-jet Model *Hrayr H. Matevosyan* Contact email: *hrayr.matevosyan@adelaide.edu.au*
HS 033	Studies of the transverse structure of the nucleon at Jefferson Laboratory *Marco Mirazita* Contact email: *Marco.Mirazita@lnf.infn.it*
HS 034	Pentaquark Θ^+ search experiment at J-PARC *M. Moritsu, S. Adachi, M. Agnello, S. Ajimura, K. Aoki, H. C. Bhang, B. Bassalleck, E. Botta, S. Bufalino, N. Chiga, H. Ekawa, P. Evtoukhovitch, A. Feliciello, H. Fujioka, S. Hayakawa, F. Hiruma, R. Honda, K. Hosomi, Y. Ichikawa, M. Ieiri, Y. Igarashi, K. Imai, N. Ishibashi, S. Ishimoto, K. Itahashi, R. Iwasaki, C. W. Joo, S. Kanatsuki, M. J. Kim, S. J. Kim, R. Kiuchi, T. Koike, Y. Komatsu, V. V. Kulikov, S. Marcello, S. Masumoto, Y. Matsumoto, K. Matsuoka, K. Miwa, T. Nagae, M. Naruki, M. Niiyama, H. Noumi, Y. Nozawa, R. Ota, K. Ozawa, N. Saito, A. Sakaguchi, H. Sako, V. Samoilov, M. Sato, S. Sato, Y. Sato, S. Sawada, M. Sekimoto, K. Shirotori, H. Sugimura, S. Suzuki, H. Takahashi, T. Takahashi, T. N. Takahashi, H. Tamura, T. Tanaka, K. Tanida, A. O. Tokiyasu, N. Tomida, Z. Tsamalaidze, M. Ukai, K. Yagi, T. O. Yamamoto, S. B. Yang, Y. Yonemoto, C. J. Yoon, K. Yoshida* Contact email: *moritsu@scphys.kyoto-u.ac.jp*
HS 035	On timelike and spacelike deeply virtual Compton scattering at next to leading order *H. Moutarde, B. Pire, F. Sabatié, L. Szymanowski, J. Wagner* Contact email: *jwagner@fuw.edu.pl*
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HS 037	Looking for meson molecules in B decays *F.S. Navarra, M. Nielsen, I. Bediaga* Contact email: *navarra@if.usp.br*
HS 038	Nuclear structure functions and parton densities at the LHeC *The LHeC Study Group* Contact email: *p.r.newman@bham.ac.uk*
HS 039	Predicting a 2.9 GeV $Df_0(980)$ molecular state *M. Nielsen, A. Martínez Torres, K. P. Khemchandani, F.S. Navarra* Contact email: *mnielsen@if.usp.br*
HS 040	Nucleon spectral function from QCD sum rules with MEM *K. Ohtani, P. Gubler, and M. Oka* Contact email: *ohtani.k@th.phys.titech.ac.jp*
HS 041	Selected TMD results from Hermes *L.L. Pappalardo* Contact email: *pappalardo@fe.infn.it*
HS 042	Strangeness Vector and Axial-Vector Form Factors of the Nucleon *Stephen Pate, Dennis Trujillo* Contact email: *pate@nmsu.edu*
HS 043	Production and Dalitz decays of baryon resonances in p+p interactions at E_{kin}=1.25 and 3.5 GeV beam energy with HADES *W. Przygoda* Contact email: *przygoda@if.uj.edu.pl*
HS 044	The Proton Form Factor Ratio Measurements at Jefferson Lab *Vina Punjabi. and Charles Perdrisat* Contact email: *punjabi@jlab.org*
HS 045	New Extraction of the Flavor Decomposition of the Nucleon Electromagnetic Form Factors *I.A.Qattan, J. Arrington* Contact email: *issam.qattan@kustar.ac.ae*
HS 046	Polarized Drell-Yan studies at COMPASS *C. Quintans* Contact email: *Catarina.Quintans@cern.ch*

HS 047	Search for permanent Electric Dipole Moments *Frank Rathmann* Contact email: *f.rathmann@fz-juelich.de*
HS 048	The incompleteness of complete pseudo-scalar meson photoproduction *J. Ryckebusch, T. Vrancx, T. Van Cuyck, P. Vancraeyveld* Contact email: *Jan.Ryckebusch@UGent.be*
HS 049	A systematic study of longitudinal and transverse helicity amplidutes in the hypercentral Constituent Quark Model *E. Santopinto and M.M. Giannini* Contact email: *santopinto@ge.infn.it*
HS 050	Valence and sea quarks in nucleon structure *E.Santopinto, R. Bijker* Contact email: *santopinto@ge.infn.it*
HS 051	Short-range correlations of partons, and 3D nucleon structure *Peter Schweitzer, Mark Strikman, Christian Weiss* Contact email: *peter.schweitzer@phys.uconn.edu*
HS 052	Determination of E and G observables in η photo-production on the CLAS Frozen Spin Target (FROST) *I. Senderovich, B. T. Morrison, M. Dugger, B. Ritchie, R. Tucker* Contact email: *senderov@jlab.org*
HS 053	Dynamically generated resonances from the vector meson-baryon octet interaction *Bao-Xi Sun* Contact email: *sunbx@bjut.edu.cn*
HS 054	Hadron spectroscopy and the search for gluonic excitations *Adam Szczepaniak* Contact email: *aszczepa@indiana.edu*
HS 055	The GPD program at COMPASS *Paweł Sznajder* Contact email: *pawel.sznajder@fuw.edu.pl*
HS 056	Low-lying pseudoscalar and vector mesons and their dynamics *Carla Terschluesen* Contact email: *carla.terschluesen@physics.uu.se*

HS 057	Electromagnetic proton form factors: perspectives for PANDA *E. Tomasi-Gustafsson* Contact email: *egle.tomasi@cea.fr*
HS 058	A nonextensive statistical model for the nucleon structure function *L.A.Trevisan, C.Mirez* Contact email: *Luisaugustotrevisan@yahoo.com.br*
HS 059	Determination of T and F observables in η photoproduction on the CLAS Frozen Spin Target (FROST) *R. Tucker, M. Dugger, B. Ritchie, I. Senderovich, B. T. Morrison* Contact email: *rtucker@jlab.org*
HS 060	Constraining ΔG at Low-x with Double Longitudinal Spin Asymmetries at Forward Rapidity at PHENIX *Scott Wolin* Contact email: *swolin2@illinois.edu*
HS 061	From Hadronic to Partonic Degrees of Freedom in Nuclear Physics *N. Zachariou* Contact email: *nicholas@jlab.org*

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Exclusive c to s, d semileptonic decays of ground-state spin-1/2 and spin-3/2 doubly heavy cb baryons

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We evaluate the semileptonic decays of ground-state spin-1/2 and spin 3/2 doubly cb baryons driven by a c to s,d transition at the quark level. Due to the finite value of the quark masses, the hyperfine interaction between the light and any of the heavy quarks can admix both S=0 and S=1 components into the wave function for spin-1/2 cb baryons. We have shown in previous works [1-3] the relevance of mixing in b to c semileptonic and electromagnetic decay involving those states. We find important corrections in this case as well, as large as a factor 2 in some cases. Besides, we have derived for the first time HQSS relations for the hadronic amplitudes that are valid in the limit of very large heavy quark masses and near zero recoil. HQSS imposes constraints on the form factors that are well satisfied by our calculation. With the use of HQSS we have derived approximate, but model independent, predictions for ratios of decay widths. Our values for those ratios evaluated within our model agree with the HQSS motivated predictions at the level of 10% in most of the cases. We expect those predictions to hold to that level of accuracy in other approaches.

Published in [4].

[1] C. Albertus, E. Hernndez, J. Nieves, Phys. Lett. B 683 (2010) 21
[2] C. Albertus, E. Hernndez, J. Nieves, Phys. Lett. B 690 (2010) 265
[3] C. Albertus, E. Hernndez, J. Nieves, Phys. Lett. B 704 (2011) 499
[4] C. Albertus, E. Hernndez, J. Nieves, Phys. Rev. D 85 (2012) 094035

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Study of the semileptonic and nonleptonic decay of the Bs meson

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We present results for different observables measured in semileptonic and nonleptonic decays of the B_s meson. The calculations have been done within the framework of a nonrelativistic constituent quark model. In order to check the sensitivity of all our results against the inter-quark interaction we use five different quarkquark potentials. We obtain form factors, decay widths and asymmetry parameters. In the limit of infinite heavy quark mass our model reproduces the constraints of heavy quark spin symmetry. For the actual heavy quark masses we find nonetheless corrections to that limiting situation for some form factors. We also analyze exclusive nonleptonic two meson decay channels within the factorization approximation.

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Nucleon mass and pion-nucleon σ-term in the covariant baryon chiral perturbation theory

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We analyse the pion mass dependence of the nucleon mass in the covariant $SU(2)$ baryon chiral perturbation theory up to the p^4-order accuracy with explicitly including $\Delta(1232)$ degrees of freedom. We perform global fits to lattice QCD data for $N_f = 2$ and $N_f = 2 + 1$ flavor ensembles with pion masses below 450 MeV. For our chiral extrapolator we use the extended-on-mass-shell renormalization scheme and also include finite volume corrections. Through the Hellmann-Feynman theorem we obtain the $\sigma_{\pi N}$-term at the physical point by the fitted low energy constants.
Presently the value for the $\sigma_{\pi N}$-term is still rather uncertain. Estimates from lattice QCD and πN scattering data range from 37 MeV to 64 MeV [1,2]. The $\sigma_{\pi N}$-term is not only a fundamental QCD object but also enters the scattering cross section prediction for dark matter searches for which a more precise value is needed [3]. In our work we use an improved chiral extrapolator, where the underlying effective field theory is the same as in [2], as compared to the one presently employed in literature.

[1] G.S. Bali, et al., Nucl. Phys., **B866**, 1 (2013).
[2] J.M. Alarcon, J. Martin-Camalich, J.A. Oller, e-Print: arXiv:1210.4450.
[3] J.R. Ellis, K.A. Olive, C. Savage, Phys. Rev., **D77**, 065026 (2008).

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Two-photon exchange contribution in elastic electron-proton scattering, experiment at the VEPP-3 storage ring

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The study of the electromagnetic form factors of the proton is crucial for the understanding of its structure. Additionally, reliable knowledge of the form factors plays an important role in many areas of the nuclear physics. However, there is a large discrepancy between the ratio of the proton electric and magnetic form factors (G_E/G_M) measurements using the old Rosenbluth separation (RS) method and ones using polarization transfer [1]. One of the most probable explanations is the contribution from two-photon exchange (TPE) effects to (ep) elastic scattering. Common practice of the analysis of RS experiments was in approximate taking into account of TPE contribution, believing this contribution to be small. Currently there are no accurate calculations of the TPE contribution, what is related to difficulties in accounting of the intermediate states of proton. But recent calculations, which take partial account of the proton structure, show importance of TPE contribution for RS analysis. The TPE contribution can be determinated directly by the measurement of R, the ratio of the (e^+p) to (e^-p) elastic scattering cross sections. But only old (in the 1960's) measurements of R exist, where the TPE contribution was found with low precision and for a limited kinematics coverage.

Present experiment [2] was performed at the VEPP-3 storage ring, Novosibirsk with the two energies of positron/electron beams: 1.6 GeV (the run was finished in 2009) and 1.0 GeV (the run was finished in 2012). The electron/positron scattering angles were $\theta = 15\div25^\circ$ and $\theta = 55\div75^\circ$ for the first case and $\theta = 65\div105^\circ$ for the second case. Electron and positron beams replaced each other regularly, one cycle with two beams required about one hour. In the first run 1100 of such cycles with the integral of luminosity $L = 324\ pb^{-1}$ were performed, in the second run we had performed 2350 cycles with $L = 600\ pb^{-1}$. The thickness of internal hydrogen gas target was about $10^{15} at/cm^2$.

The data analysis, besides the other things, includes small corrections related to the energy and position differences of electron and positron beams as well the radiative corrections. Radiative corrections significantly reduce the raw R and they should be calculated accurately [3].

Description of the experiment and results of the data analysis will be presented.

[1] A. J. R. Puckett, et al., Phys. Rev. C 85, 045203 (2012).
[2] J. Arrington, V.F. Dmitriev, R.J. Holt, D.M. Nikolenko, I.A. Rachek, Yu.V.Shestakov,V.N. Stibunov, D.K. Toporkov, H.de Vries, Two-photon exchange and elastic scattering of electrons/positrons on the proton. (Proposal for an experiment at VEPP-3), arXiv:nucl-ex/0408020.
[3] A.V. Gramolin, J. Arrington, L.M. Barkov, et al., Measurement of the two-photon exchange contribution in elastic ep scattering at VEPP-3, arXiv:nucl-ex/1112.5369

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SEARCH FOR HIGHER LYING CHARMONIUM AND EXOTICS IN EXPERIMENTS USING HIGH QUALITY ANTIPROTON BEAM WITH MOMENTUM UP 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, branching ratio) in experiments using high quality antiproton beam with momentum up to 15 GeV/c, is 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_J, ^3D_J charmonium states and higher laying scalar $^1S_0$ and vector $^3S_1$ charmonium states are poorly investigated. The domain above $D\overline{D}$ threshold of 3.73 GeV/c^2 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, charmed hybrids and tetraquarks with hidden charm was carried out, and the attempts to interpret a great quantity of experimental data above $D\overline{D}$ 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 higher lying states of charmonium, charmed hybrids and tetraquarks are expected to exist in the mass region above $D\overline{D}$ threshold. But much more data on different decay modes are needed for deeper analysis. These data can be derived directly from the experiments with high quality antiproton beam.

Especial attention is given to the new states with the hidden charm (XYZ-particles) discovered recently. Their interpretation is far from been obvious nowadays [2]. The experimental data from different collaborations were carefully studied. Some of these states can be interpreted as higher laying states of charmonium and tetraquarks. This treatment seems to be perspective and needs to be carefully verified in the experiments using antiproton beam with momentum ranging from 1 to 15 GeV/c.

[1] PANDA Collaboration, Physics Performance Report, P.63 (2009);
[2] N.Brambilla *et al.*, European Physical Journal C 71:1534, P.1 (2011).

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Spin alignment and OZI violation in exclusive ϕ and ω production in pp collisions at COMPASS

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The COMPASS collaboration has investigated the exclusive production of ϕ and ω mesons with a 190 GeV proton beam on a liquid hydrogen target with the aim to explore the interplay of several production mechanisms. The ratio between the ϕ and ω cross sections is determined as well as its dependence on x_F of the leading proton and the mass of the system consisting of leading proton and vector meson, $M(pV)$. We find a significant violation of the Okubo-Zweig-Iizuka (OZI) rule with a clear dependence on x_F and $M(pV)$. If the kinematic region is excluded from the data, for which an abundance of omega-baryon resonances is observed, the OZI violation is found to be independent of x_F. Furthermore, the spin alignment of the vector mesons is measured within a set of reference frames which are sensitive to different production mechanisms. Again, dependences of the alignment on x_F and $M(pV)$ are found, which differ significantly for ϕ and ω.
This work is supported by the BMBF.

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Dalitz plot analysis for $\eta \to \pi^+\pi^-\pi^0$ at KLOE

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The isospin-violating process $\eta \to \pi^+\pi^-\pi^0$ is sensitive to the light quark mass ratio:

$$Q^2 = \frac{m_s^2 - \hat{m}^2}{m_d^2 - m_u^2}, \text{ where } \quad \hat{m} = \frac{1}{2}(m_d + m_u) \tag{1}$$

in that the decay rate is proportional to Q^{-4}. The values for this decay rate, calculated at leading order ($\Gamma_{LO} \sim 70$ eV) and next-to-leading order ($\Gamma_{NLO} = 160 \pm 50$ eV) in χPT are significantly lower than the experimental value $\Gamma_{exp} = 296 \pm 16$ eV , obtained from a fit to all the available data[1]. This points to a slow convergence of the χPT series, due to strong pion rescattering effects in the final state, wich can be treated by means of dispersion relations[2].

In 2008, the KLOE collaboration published the Dalitz plot analysis of the $\eta \to \pi^+\pi^-\pi^0$ with the most statistics to date[3]. The results have been used to fix the parameters of the dispersion relations[4] and in analytic dispersive analysis[5]. More data on $\eta \to \pi^+\pi^-\pi^0$ Dalitz plot are needed to understand the origin of the residual tension between data and theoretical calculations.

A new analysis by KLOE is in progress to improve on the statistical sample and to overcome some limitations of the previous analysis. For this, a new selection scheme is used. The selection efficiency is planned to be measured directly from minimum bias events, to reduce systematic errors. The analysis is performed on an independent, larger data sample. The status of this analysis will be presented.

[1] K. Nakamura et al. (Particle Data Group), *Journal of Physics* G**37**, 075021 (2010);
[2] G. Colangelo, S. Lanz and E. Passemar *Proceedings of Science*, arXiv:0910.0765 (2009).
[3] Ambrosino *et al.* (The KLOE collaboration), *JHEP*, **Vol 5**, page 006, arXiv:1102.4999 (2008);
[4] S. Lanz, "Berne-Lund-Valencia Dispersive Treatment of $\eta \to 3\pi$", talk at International PrimeNet Workshop, Jülich, September 26-28 2011, and contribution to these Proceedings;
[5] M. Zdrahal, "Prague-Lund-Marseille Dispersive Treatment of $\eta \to 3\pi$", talk at International PrimeNet Workshop, Jülich, September 26-28 2011, and contribution to these Proceedings.

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Chiral Structure of Light Scalar Mesons and Scalar Tetraquarks Currents

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The quark model is very successful in explaining the hadron spectrum with simply using $\bar{q}q$ mesons and qqq baryons. However, there are always multi-quark components in the Fock-space expansion of hadron states. Besides these "exotic" components, multi-quark states themselves are also important in order to understand the low-energy behavior of QCD. Particulary, the light scalar mesons, $\sigma(500)$, $\kappa(800)$, $a_0(980)$ and $f_0(980)$, are good candidates due to their tetraquark (or molecular) components. They are considered as tetraquark states or containing large tetraquark components [1].

To study the multi-quark components of the light scalar mesons, we can use group theoretical methods, which have been applied to study quark-antiquark mesons and three-quark baryons [2,3,4,5]. We systematically classified the scalar tetraquark currents and found that there are altogether as many as five independent scalar local tetraquark currents for each flavor structure [6]. Therefore, right currents should be used in order to study light scalar mesons. This is also closely related to the internal structure of light scalar mesons.

In order to find out the right currents, we systematically study the chiral structure of light scalar mesons through local tetraquark currents which belong to the "non-exotic" $[(\bar{\mathbf{3}}, \mathbf{3}) \oplus (\mathbf{3}, \bar{\mathbf{3}})]$ chiral multiplets. This chiral multiplet only contains flavor singlet and octet mesons, and it does not contain any meson having exotic flavor structure. Since there are no experimental signals observing scalar mesons having exotic flavors, we assume that all the nine light scalar mesons (or their dominant components) belong to this multiplet. Moreover, these nine light scalar mesons can just compose one $[(\bar{\mathbf{3}}, \mathbf{3}) \oplus (\mathbf{3}, \bar{\mathbf{3}})]$ chiral multiplet.

To do a systematical study, we investigate both scalar and pseudoscalar tetraquark currents, since they are chiral partners [7]. We then used these currents and performed the QCD sum rule analysis to calculate their masses. The masses of σ, κ, a_0 and f_0 are around 0.56 ± 0.05 GeV, 0.88 ± 0.09 GeV, 1.06 ± 0.10 GeV and 1.06 ± 0.10 GeV, respectively, generally consistent with the experimental values. However, the pole contributions are very small. Then we introduced a few $[(\mathbf{8}, \mathbf{1}) \oplus (\mathbf{1}, \mathbf{8})]$ components by slightly changing the mixing parameters among different tetraquark currents. The masses of σ, κ, a_0 and f_0 are now around $400 \sim 460$ MeV, $620 \sim 760$ MeV, $820 \sim 1020$ MeV and $820 \sim 1020$ MeV, respectively, better consistent with the experimental results. The pole contributions are significantly increased to be around 50% for $\sigma(500)$ and $\kappa(800)$.

[1] R. L. Jaffe, Phys. Rev. D **15**, 267 (1977); R. L. Jaffe, Phys. Rev. D **15**, 281 (1977).
[2] S. Weinberg, Phys. Rev. **177**, 2604 (1969); S. Weinberg, Phys. Rev. Lett. **65**, 1177 (1990).
[3] D. B. Leinweber, Phys. Rev. D **53**, 5115 (1996).
[4] B. L. Ioffe, Z. Phys. C **18**, 67 (1983).
[5] T. D. Cohen and X. D. Ji, Phys. Rev. D **55**, 6870 (1997).
[6] H. X. Chen, A. Hosaka and S. L. Zhu, Phys. Rev. D **76**, 094025 (2007).
[7] H. -X. Chen, Eur. Phys. J. C **72**, 2204 (2012).

First measurement of the helicity dependence of ^{3}He photo-reactions in the $\Delta(1232)$ resonance region

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The first measurement of the helicity dependence for several photo-reaction channels on ^{3}He was carried out in the photon energy range between 150 and 500 MeV. The experiment was performed at the tagged photon facility of the MAMI accelerator in Mainz, using the large acceptance Crystal Ball spectrometer, complemented by charged particle and vertex detectors. A circularly polarised tagged photon beam and a longitudinally polarised high-pressure ^{3}He gas target were used [1]. These new experimental results provide information on the Gerasimov-Drell-Hearn (GDH) sum rule on the neutron and allow an investigation of the nucleon properties inside ^{3}He and of the effects of three-nucleon photon absorption mechanisms. Due to the ^{3}He spin structure, these data give complementary and a more direct access to the polarised neutron with respect to the existing data on the deuteron.

As an example, Fig. 1 shows the helicity-dependent total cross section $\Delta\sigma$ for the reaction channels γ^3He $\rightarrow \pi^0 X$, γ^3He $\rightarrow \pi^\pm X$ and γ^3He $\rightarrow ppn$. $\Delta\sigma$ is $\sigma_\mathrm{p} - \sigma_\mathrm{a}$, where p (a) refers to the relative (anti)parallel γ ^{3}He spin orientation. The data for the first two reaction channels are compared to the predictions of the Fix-Arenhövel model (FA) and of the SFSN model. The first one includes the momentum distribution of the nucleons inside ^{3}He as well as the effects of final state interaction [2]. The other one is a pure incoherent Sum of Free Single Nucleon (SFSN) cross sections determined using the MAID multipole analysis [3] and takes into account only the effects of the neutron spin alignment in ^{3}He.

As clear from Fig. 1, state-of-the-art calculations are unable to describe in a satisfactory manner the helicity-dependent cross section for the πX channels, while no model is currently available for the ppn channel. The same is true for the unpolarised data that were also obtained.

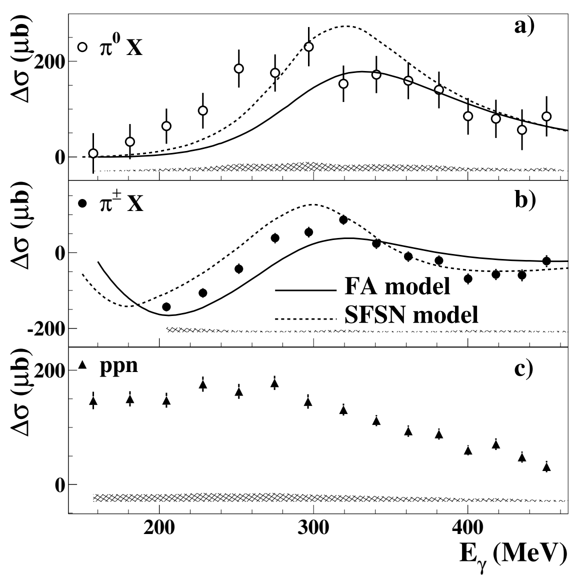

Figure 1: *Helicity dependent cross section $\Delta\sigma$ for a) $\gamma^3He \rightarrow \pi^0 X$, b) $\gamma^3He \rightarrow \pi^\pm X$ and c) $\gamma^3He \rightarrow ppn$. The error bars are statistical and the hatched bands show the systematic uncertainties.*

[1] P. Aguar Bartolomé et al., submitted to Phys. Lett. B (2012);

[2] H. Arenhövel and A. Fix, Phy. Rev. C 72, 064004 (2005);

[3] D. Drechsel et al., Eur. Phys. J. A 34, 69 (2007).

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Neutron transverse-spin distributions onto the Light-front plane and the polarized ^{3}He target

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A realistic study of the semi-inclusive deep inelastic scattering (SiDIS) process $^3He(e, e'\pi)X$ is of primary importance in view of the forthcoming high luminosity experiments, planned at Thomas Jefferson National Accelerator Facility for extracting the transversity distribution inside the neutron [1].

As it is well known, the quark polarizations take into account at most one-third of the nucleon polarization. This motivates the great effort on both experimental and theoretical sides for elucidating such an issue, and accurately evaluating the contributions from the quark orbital angular momentum (L_q) and the gluons.

Information on the so-called quark transverse-momentum distributions (TMDs), and in turn on L_q, can be accessed through non-forward processes, like SiDIS. In particular, a transversely polarized ^3He target is an ideal target to study a transversely polarized neutron, since at 90% level it is equivalent to a polarized neutron target.

Our aim is to study relativistic effects in the actual experimental kinematics [1]. In view of that, we present a novel *fully Poincaré covariant description* of the nuclear target [2], implementing a Light-Front (LF) analysis at finite Q^2, within the Bakamijan-Thomas construction of the Poincaré generators (see [3,4] for a presentation of the approach in the Bjorken limit). The main ingredient of our approach is the LF spin-dependent spectral function for a J=1/2 system [2], fully determined by three independent scalar functions. Within such a framework, the final-state interaction between the jet produced from the hadronizing quark and the two-nucleon spectator system will be included through a Glauber approach. The present approach extends previous, non Poincaré covariant, investigations carried out within the impulse approximation in the Bjorken limit [5].

Furthermore, as a by-product, our analysis can be straightforwardly applied for describing the particle contribution to the *nucleon quark-quark correlator*, obtaining exact linear relations between the six T-even leading-twist TMDs. It is worth noting that, within our LF approach with fixed number of degrees of freedom, TMDs result to be expressed in terms of only three independent scalar functions [2]. These relations are completely new and could be experimentally checked to test the LF description of SiDIS in the valence region.

[1] TJLab experiments E12-09-018 and E12-10-006, web page: http://hallaweb.jlab.org/12GeV/
[2] A. Del Dotto, E. Pace, M. Rinaldi, G. Salmè and S. Scopetta, to be published.
[3] S. Scopetta, A. Del Dotto, E. Pace and G. Salmè "Transversity studies with a polarized ^3He target" IL NUOVO CIMENTO, **C35**, 101 (2012); Acta Physica Polonica **6**, (2013), DOI:10.5506/APhysPolBSupp.6.1001.
[4] A. Del Dotto, E. Pace, M. Rinaldi, G. Salmè and S. Scopetta "Neutron Transverse-Momentum Distributions and Polarized ^{3}He within Light-Front Hamiltonian Dynamics", arXiv 1301.5787 and Few-Body Syst. in press.
[5] S. Scopetta, "Neutron single spin asymmetries from semi-inclusive deep inelastic scattering off transversely polarized 3He" Phys. Rev. **D 75** 054005 (2007).

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Gluon polarization and jet production at STAR

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At RHIC kinematics, polarized jet hadroproduction is dominated by *gg* and *qg* scattering, making the jet double-helicity asymmetry, A_{LL}, sensitive to gluon polarization in the nucleon. Previous STAR measurements of A_{LL} for inclusive jet production at $\sqrt{s}$ = 200 GeV during the 2006 RHIC run [1] provided significant constraints on the gluon contribution to the proton spin over the Bjorken-x range $0.05 < x < 0.2$ [2]. Recently, STAR has released preliminary measurements of A_{LL} for inclusive jet and di-jet production at $\sqrt{s}$ = 200 GeV from a much larger data set recorded during 2009 [3,4]. These preliminary results provide the first experimental evidence of non-zero gluon polarization in the x range sampled at RHIC [5]. Since then, substantial progress has been made on reducing and finalizing the systematic uncertainties in the 2009 inclusive jet A_{LL} measurement. In this talk, I will discuss the STAR jet A_{LL} measurements and their implications for the gluon polarization in the proton. I will also discuss STAR future plans for more high-precision jet data at $\sqrt{s}$ = 200 GeV and 500 GeV.

[1] L. Adamczyk *et al*. (STAR Collaboration), Phys. Rev. D **86**, 032006 (2012).
[2] D. de Florian, R. Sassot, M. Stratmann, and W. Vogelsang, Phys. Rev. Lett. **101**, 072001 (2008).
[3] P. Djawotho (STAR Collaboration), arXiv:1106.5769.
[4] M. Walker (STAR Collaboration), arXiv:1107.0917.
[5] D. de Florian, R. Sassot, M. Stratmann, W. Vogelsang, Prog. Part. Nucl. Phys. **67**, 251 (2012).

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Study of the proton structure by measurements of polarization transfers in Wide Angle Real Compton scattering at JLab

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Real Compton Scattering (RCS) in the hard scattering limit is a powerful probe of the structure of the nucleon; the two photon couplings allow to access information which are complementary to DIS and elastic electron scattering. RCS experiments, devoted to measure the components of the recoil proton polarization with longitudinally polarized incident photons, have been performed in Hall A and Hall C in the recent past [1]. In the hard scale, when Mandelstam variables s, $-t$ and $-u$ are all large compared to the proton mass, the transition amplitude is expected to factorize into the convolution of a perturbative hard scattering amplitude with an overlap of initial and final soft non-perturbative wave functions. Different factorization schemes have been applied to RCS and these can be distinguished by the number of active constituents participating in the hard scattering subprocess [2],[3].

A remarkable result from JLab [4] has shown that the longitudinal polarization transfer is consistent with the "handbag" prediction and completely inconsistent with a prediction based on pQCD, two of the most explored mechanisms. This result requires additional measurements over a broader kinematic range, at higher photon energy for a better experimental verification of the handbag description. Furthermore, RCS could also shed light on the Generalized Parton Distributions (GPDs), one of the most promising theoretical tool to determine the total angular momentum contribution of quarks and gluons to nucleon spin. In this respect, Hall C experiment is expected to provide additional information on the RCS mechanism in the hard regime, at three large values of the center of mass proton scattering angle (70, 90, 110), at large energy (s = 9 $(GeV/c)^2$). The experiment has utilized an untagged, longitudinally polarized bremsstrahlung photon beam generated by the CEBAF electron beam on a copper radiator. The photons have been scattered from a liquid hydrogen target, transferring polarization to the recoil protons. Scattered photon and recoil protons have been detected in coincidence. A focal plane polarimeter measures the polarization of the recoiling protons by the azimuthal asymmetry in the angular distribution of protons scattered in carbon based analyzers.

The analysis of the collected data is underway with the main aim to extract the three polarization observables of the RCS process K_{LL}, K_{LT} and P_N with excellent accuracy, providing consolidated validation of the handbag reaction mechanism. Byproduct of the experiment is the measurement of the ratio of the transverse and longitudinal polarization recoil proton components, which is directly proportional to the ratio of the electromagnetic proton form factors.

The preliminary results of the data analysis will be presented.

[1] R. Gilman, A. Nathan, B. Wojtsekhowski (spokespeople), Polarization transfer in Wide Angle Compton Scattering, A proposal to Jefferson Lab PAC31 (2006).
[2] A.V. Radyushkin, **Phys. Rev. D 58**, 114008 (1998).
[3] G. R. Farrar and H. Zhang, **Phys. Rev. Lett. 41**, (1990) 1721, **Phys. Rev. D 65** 3348 (1990).
[4] D. J. Hamilton, V. H. Mamyan et al., **Phys. Rev. Lett. 94**, 242001 (2005).

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Molecular structures in heavy meson and baryon spectrum

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In different charmonium sectors several resonances like the X(3872), X(3915), G(3900), etc, has been reported in the last time without a clear theoretical interpretation in terms of $c\bar{c}$ pairs. Even in the baryon spectrum, resonances like the $\Lambda_c^+(2940)$ are a challenge for theoretical models. In this work we propose a theoretical explanation for this kind of phenomena as molecular structures coupled or not to $q\bar{q}$ states. We work in the framework of a coupled channel calculation [1] generalized to include several meson-antimeson channels, several $q\bar{q}$ states below and resonances above threshold.

The $q\bar{q}$ states are found solving the Schrödinger equation in the framework of the constituent quark model of Ref. [2]. This model includes pion exchanges between quarks which is very important to describe the $D\bar{D}$ and Dp interaction The meson-antimeson interaction is consistently obtained using the Resonating Group Method with these wave functions and interaction. Finally we couple the $q\bar{q}$ states with the $q\bar{q}q\bar{q}$ states using the microscopic $^3P_0$ model.

In this calculation the well known X(3872) resonance appears as a DD^* molecule coupled to a $\chi_{c_1}(2P)$ $c\bar{c}$ state. The original $\chi_{c_1}(2P)$ acquires a significant DD^* component and can be identified with the X(3940). In the 0^{++} sector we include in the calculation the $\chi_{c0}(2P)$ $c\bar{c}$ state and the DD, $J/\psi\omega$, D_sD_s and $J/\psi\phi$ meson-antimeson states. We find two states which can be identified with the $X(3915)$ and with the sometimes called $Y(3940)$. In the 1^{--} sector we obtain one new molecular state that could be assigned to the $G(3940)$ with an important dressing of the well established $\psi(4040)$ and $\psi(4160)$. Physical consequences of this dressing are discussed.

Concerning the baryon sector, we have extended the calculation to DN and BN molecules. We have identified the $\Lambda_c(2940)^+$ baryon as a $J^P = \frac{3}{2}^-$ D^*N molecule [3]. We have study the decay channels $\Lambda_c(2940)^+ \to D^0p$, $\Lambda_c(2940)^+ \to D^+n$, $\Lambda_c(2940)^+ \to \Sigma_c^{++}\pi^-$, $\Lambda_c(2940)^+ \to \Sigma_c^+\pi^0$ and $\Lambda_c(2940)^+ \to \Sigma_c^0\pi^+$. The obtained widths of the D^0p and D^+n decay channels are of the order of the experimental data whereas the contributions of the $\Sigma_c\pi$ channels are negligible. The predicted total width agrees with experimental data .

Moreover we predict in the same model the existence of new resonances in the BN $D\Delta$ and $B\Delta$ channels with a relatively small width which can be discovered at LHCb in the near future.

[1] V. Baru *et al.*, Eur. Phys. J. A **44**, 93 (2010). Phys. Rev. D **79**, 092001 (2009).

[2] J. Vijande, F. Fernández, and A. Valcarce, J. Phys. G **31**, 481 (2005).

[3] P: G. Ortega, D. R. Entem, F. Fernández Phys. Lett B in Press and arXiv:1210.2633

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Strangeness content of the proton in the unquenched quark model

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We discuss the results of an unquenched quark model (UCQM) [1] calculation of the $s\bar{s}$ sea pairs' contribution to the magnetic moment of the proton (the strange magnetic moment) and its charge radius (the strange radius) [2]. In our approach, the effects of the $s\bar{s}$ pairs are introduced explicitly into the constituent quark model through a microscopic, QCD inspired, quark-antiquark pair creation mechanism. Our results for the two observables are compatible with the most recent experimental data [3] and lattice QCD calculation [4].

[1] E. Santopinto and R. Bijker, Few Body Syst. 44, 95 (2008); Phys. Rev. C 82, 062202 (2010); R. Bijker and E. Santopinto, Phys. Rev. C 80, 065210 (2009); J. Ferretti, G. Galatà, E. Santopinto and A. Vassallo, Phys. Rev. C 86, 015204 (2012).
[2] R. Bijker, J. Ferretti and E. Santopinto, Phys. Rev. C 85, 035204 (2012).
[3] R. Hasty *et al.* (SAMPLE Collaboration), Science 290, 2117 (2000); A. Acha *et al.* (HAPPEX Collaboration), Phys. Rev. Lett. 98, 032301 (2007); S. Baunack *et al.* (A4 Collaboration), Phys. Rev. Lett. 102, 151803 (2009); D. Androic *et al.* (G0 Collaboration), Phys. Rev. Lett. 104, 012001 (2010).
[4] D. B. Leinweber *et al.*, Phys. Rev. Lett. 94, 212001 (2005); 97, 022001 (2006); T. Doi *et al.*, Phys. Rev. D 80, 094503 (2009).

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Confinement in QCD and the interquark potential

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Recent studies on lattice have produced a well defined result for the gluon propagator in the low-energy limit. Such a solution has been dubbed "decoupling" and implies a massive gluon in the infrared. Starting from this, we analyze the Wilson loop for a pure Yang-Mills theory and show that, at one-gluon exchange level, it is seen that the potential cannot yield a linear rising contribution as expected for a confining theory. But the next-to-leading order correction gives rise to a quartic term for momenta in the gluon propagator that, in agreement with Gribov's view, yields a linear confining term. This correction is due to a two-loop or sunrise integral that we need to evaluate in the low-momenta limit. In the infrared regime, the physical consistency of the theory is determined by a natural cut-off, arising from the integration of the classical equations of the theory, fixing in this way the regularization scheme. Then, a closed form for the interquark potential is given and the string tension for a linear rising potential is obtained.

[1] M. Frasca, arXiv:1110.2297 [hep-ph].
[2] M. Frasca, arXiv:1208.3756 [hep-ph], to appear in Nuclear Physics B: Proceedings Supplements.
[3] M. Frasca, Phys. Rev. C 84, 055208 (2011).

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Charmonia and bottomonia hybrid predictions

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The hybrids are mesons with constituent gluonic components. The most commonly studied hybrids are composed of a quark, an antiquark and a gluon. These mesons are studied in these works in a variational approach to QCD in the Coulomb gauge. This particular gauge has been chosen for its advantages, in particular in the Coulomb gauge the degrees of freedom are physical. This makes the QCD Hamiltonian close in spirit to quantum mechanical models of QCD, for example the constituent quark model, and particularly adapt to calculate the spectrum of particles. In our variational approach we used a variational gaussian vacuum on which the quasiparticle states were built. This variational approach to Coulomb gauge QCD has been developed as a method to introduce effective degrees of freedom (constituent gluons and quarks) in such a way that the connection to QCD is not destroyed. The vacuum expectation value (VEV) of the Coulomb gauge Hamiltonian was calculated and the variational principle applied, resulting in a set of four coupled Dyson-Schwinger equations. Unfortunately the VEVs cannot be calculated exactly, mainly due to the difficulty to deal with the Faddeev-Popov operator, and theoretical approximations, such as the rainbow ladder approximation, had to be adopted. This makes the model an effective one but with still strong connection to QCD. Within the variational approach and with the approximations used, a confining linear potential has been shown to emerge from the Dyson-Schwinger equations, at least at the hadronic scale. This potential has been used to first calculate the spectrum of the gluelump [1], which is an idealized system defined as gluonic excitations bounded to a static, localized color octet source (for example a very heavy quark and antiquark). The gluelump states could be classified according to the JPC quantum numbers and we found that the ordering of the various spin-parity states matches those found in lattice computations [1]. The absolute energy scale of these levels is set by the variational parameter. We were able to reproduce the lattice data and in particular the inversion of the gluelump unnatural parity state 1+- below the natural parity state 1–, which is typical of the lattice results. The next step has been to introduce the quark-antiquark dynamics to calculate the spectrum of heavy hybrid mesons [2]. The relation between heavy hybrids and gluelumps is very close: low hybrids are expected to be approximately classified by the product of gluelump and antiQ Q quantum numbers. The final and more important result is the good agreement found between our results and the lattice ones. Again we reproduced in particular the inversion of the 1–, 0-+, 1-+, 2-+ hybrids (which correspond to the 1+- gluelump) below the 1+-, 0++, 1++, 2++ hybrids (which correspond to the 1– gluelump) and we were able to explain the physical reasons of this inversion [2].

[1] Peng Guo, Adam Szczepaniak, Giuseppe Galat, Andrea Vassallo and Elena Santopinto, Gluelump spectrum from Coulomb gauge QCD. Phys. Rev.D77:056005,2008. e-Print: arXiv:0707.3156[hep-ph];

[2] Peng Guo, Adam Szczepaniak, Giuseppe Galat, Andrea Vassallo and Elena Santopinto, Heavy quarkonium hybrids from Coulomb gauge QCD. Phys.Rev.D78:056003,2008. e-Print: arXiv:0807.2721[hep-ph].

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Nucleon structure through Generalized Parton Distributions

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Generalized Parton Distributions provide a 3-dimensional description of hadronic structures in terms of partonic longitudinal momentum and transverse position. They appear as universal functions parameterizing the factorized amplitudes for exclusive scattering in the Bjorken limit. After a decade of exploratory measurements, we are now in a transition towards a new phase of precision mapping. We will review the existing data from Jefferson Laboratory, and their impact on extraction strategies. A full program combining beam and target polarizations will be carried out for these extractions, requiring as well various meson productions in the final state for flavor separation.

Chiral Dynamics and Transverse Peripheral Densities

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We study the transverse charge, current and matter densities in the periphery of the nucleon where they are governed by universal chiral dynamics. The large–distance asymptotics of the densities are derived from the spectral functions of the Dirac and Pauli form factors near the threshold at $t = 4M_\pi^2$ obtained from invariant chiral perturbation theory. In the equivalent light–front formulation, the peripheral densities arise from large–size πN configurations in the nucleon's light–front wave function obtained from the chiral Lagrangian. We compute the chiral component of the charge and current densities and explain their order–of–magnitude in the chiral expansion in a simple physical picture. We also discuss the role of π*Δ* intermediate states and the heavy–baryon expansion of peripheral densities, and comment on progress extending an analogous analysis concerning transverse densities from form factors of the energy-momentum tensor and its connections with studies on GPDs.

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High-Accuracy Analysis of Compton Scattering in Chiral EFT: Status and Future

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Compton scattering from protons and neutrons provides important insight into the structure of the nucleon. For photon energies below 300 MeV, the process is parameterised by six dynamical dipole polarisabilities which characterise the two-photon response to a monochromatic photon of fixed frequency and multipolarity. Their zero-energy limit are the static electric and magnetic scalar dipole polarisabilities α_{E1} and β_{M1}, and the four spin-polarisabilities. A new extraction of the static electric and magnetic scalar dipole polarisabilities of the proton and neutron from all published elastic data below 300 MeV in Chiral Effective Field Theory was performed in Refs. [1,2]: $\alpha_{E1}^{(p)} = 10.7 \pm 0.4(\text{stat}) \pm 0.2(\text{Baldin}) \pm 0.3(\text{theory})$, $\beta_{M1}^{(p)} = 3.1 \mp 0.4(\text{stat}) \pm 0.2(\text{Baldin}) \mp 0.3(\text{theory})$ for the proton, and $\alpha_{E1}^{(n)} = 11.1{\pm}1.8(\text{stat}){\pm}0.4(\text{Baldin}){\pm}0.8(\text{theory})$, $\beta_{M1}^{(n)} = 4.2{\mp}1.8(\text{stat}){\pm}0.4(\text{Baldin}){\pm}0.8(\text{theory})$ for the neutron, both in units of 10^{-4} fm^3, and after applying the Baldin Sum Rule constraint. Within the statistics-dominated errors, the proton and neutron polarisabilities are thus still identical, i.e. no iso-spin breaking effects of the pion cloud are seen. Particular attention is paid to the precision and accuracy of each data set, and to an estimate of residual theoretical uncertainties. ChiEFT is ideal for that purpose since it has a model-independent estimate of higher-order corrections built-in and encodes the correct low-energy dynamics of QCD, including, for few-nucleon systems used to extract neutron polarisabilities, consistent nuclear currents, rescattering effects and wave functions. It therefore automatically respects the low-energy theorems for photon-nucleus scattering. The $\Delta(1232)$ as active degree of freedom is essential to realise the full power of the world's Compton data. Its parameters are constrained in the resonance region. In view of ongoing effort at HIγS, MAMI and MAXlab, desirable improvements of the database are discussed. Single- and doubly-polarised observables can be used to extract not only scalar nucleon polarisabilities, but also the so-far poorly explored spin-polarisabilities. They parametrise the stiffness of the nucleon spin in external electro-magnetic fields.

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[1] H. W. Grießhammer, J. A. McGovern, D. R. Phillips and G. Feldman: Prog. Part. Nucl. Phys. **67** (2012), 841 [arXiv:1203.6834 [nucl-th]].

[2] J. A. McGovern, D. R. Phillips and H. W. Grießhammer: accepted for publication in Europ. J. Phys. **A** [arXiv:1210.4104 [nucl-th]].

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Generalized Parton Distributions:

a general unifying tool for exploring the internal structure of hadrons

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The Generalized Parton Distributions (GPDs) allow to characterize the dynamics of partons inside the nucleon in a unique way. They are 2-parton correlation functions which, for instance, describe the longitudinal momentum dependence of the partons as a function of their transverse position, thus correlating the parton distribution function information accessed in deep inelastic scattering with the form factor information accessed in lepton nucleon elastic scattering. Among other features, they allow to access the (unknown) angular momentum contribution of the quarks to the nucleon spin.

GPDs are accessed experimentally through hard exclusive leptoproduction reactions on the nucleon, in particular Deep Virtual Compton Scattering (DVCS). We will present the worldwide DVCS experimental program and all the recent data issued from the Jefferson Lab and DESY facilities. We will show the results of some first global fitter codes which begin to extract from these data some new insights on nucleon structure. Future directions in this active field will be discussed.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Transverse target single-spin asymmetry in inclusive electroproduction of charged pions and kaons

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Single-spin asymmetries in inclusive production of hadrons in hadron-nucleon have for a long time attracted and puzzled hadron-physics phenomenology. The large asymmetries observed were not compatible with the notion of collinear moving partons, and alternative explanation had to be found. Two approaches that go beyond the standard leading-twist collinear approach need to be confronted with data: one is based on twist-three collinear multi-parton dynamics, the other on explicit dependence of parton distribution and fragmentation functions on transverse parton momenta.

At the HERMES experiment single-spin asymmetries were investigated in inclusive electroproduction of charged pions and kaons from a transversely polarized hydrogen target using the 27.G GeV lepton beam at HERA. The asymmetries were studied as a function of the azimuthal angle ψ about the beam direction between the target-spin direction and the hadron production plane, the transverse hadron momentum, P_T, relative to the direction of the incident beam, and the Feynman variable x_F. The $\sin\psi$ amplitudes are positive for π^+ and K^+, slightly negative for π^- and consistent with zero for K^-, with particular P_T but weak x_F dependences. Especially large asymmetries were observed for two small subsamples of events, where also the scattered electron was recorded by the spectrometer.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Comparative study of nonperturbative charm in the nucleon

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We perform a comprehensive analysis of the possible role of nonperturbative (or intrinsic) charm in the nucleon. We compare and contrast various nonperturbative models, including five-quark Fock state expansions of the nucleon wave function and meson-baryon models involving asymmetric dissociation into charm mesons and baryons. Particular attention is paid to the existence and persistence of high-x structure for intrinsic charm. In addition we study the fraction of the proton momentum carried by charmed quarks as well as predictions for the $c - \bar{c}$ asymmetry from meson–baryon models. We discuss how studies of charm baryons and mesons in hadronic interactions can be used to constrain models, and outline future measurements that could further illuminate the intrinsic charm contribution.

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Production of doubly charmed tetraquarks with exotic color configurations in electron-positron collisions

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Structure and production of doubly charmed tetraquarks $\mathrm{T_{cc}}$ $(\mathrm{cc\bar{u}\bar{d}})$ are studied from the viewpoint of color configurations [1]. Based on the diquark correlation, the tetraquark $\mathrm{T_{cc}}$ with $I(J^P) = 0(1^+)$ is considered to be stable against strong decay. In addition to the conventional $\mathrm{T_{cc}}$ with cc pair in color antitriplet ($\mathrm{T_{cc}}[\bar{\mathbf{3}}, {}^{\mathbf{3}}\mathrm{S}_{\mathbf{1}}]$), we consider the $\mathrm{T_{cc}}$ with cc pair in color sextet ($\mathrm{T_{cc}}[\mathbf{6}, {}^{\mathbf{1}}\mathrm{S}_{\mathbf{0}}]$). The color sectet quark-quark correlation is exotic, because it does not exist in normal $\bar{\mathrm{q}}\mathrm{q}$ and qqq hadrons. We discuss that the mixing probability of $\mathrm{T_{cc}}[\bar{\mathbf{3}}, {}^{\mathbf{3}}\mathrm{S}_{\mathbf{1}}]$ and $\mathrm{T_{cc}}[\mathbf{6}, {}^{\mathbf{1}}\mathrm{S}_{\mathbf{0}}]$ is suppressed by $1/m_c^2$, so the two configurations are separately realized in the heavy quark limit.

Utilizing the nonrelativistic QCD framework [2], we evaluate the production cross sections of $\mathrm{T_{cc}}$ in electron-positron collisions. In Fig. 1, we show the differential cross section $\mathrm{d}\sigma/\mathrm{d}p\,\mathrm{d}\cos\Theta$ at $\sqrt{s} = 10.6$ GeV. The momentum dependence of the cross section of $\mathrm{T_{cc}}[\bar{\mathbf{3}}, {}^{\mathbf{3}}\mathrm{S}_{\mathbf{1}}]$ is found to be different from that of $\mathrm{T_{cc}}[\mathbf{6}, {}^{\mathbf{1}}\mathrm{S}_{\mathbf{0}}]$, which can be used to discriminate the color structure of the $\mathrm{T_{cc}}$ states in experimental measurements.

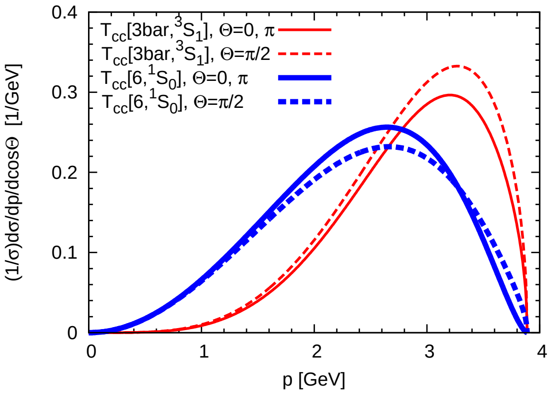

Figure 1: *Differential cross section as functions of the magnitude of the three momentum of* $\mathrm{T_{cc}}$. *Thin (thick) lines represent the production of* $\mathrm{T_{cc}}[\bar{\mathbf{3}}, {}^{\mathbf{3}}\mathrm{S}_{\mathbf{1}}]$ *(*$\mathrm{T_{cc}}[\mathbf{6}, {}^{\mathbf{1}}\mathrm{S}_{\mathbf{0}}]$*).*

[1] T. Hyodo, Y. -R. Liu, M. Oka, K. Sudoh and S. Yasui, arXiv:1209.6207 [hep-ph];
[2] G. T. Bodwin, E. Braaten and G. P. Lepage, Phys. Rev. D 51, 1125 (1995) [Erratum-ibid. D 55, 5853 (1997)].

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Fragmentation and quark distribution functions for the pion and kaon with explicit flavor-SU(3)-symmetry breaking

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We investigate the unpolarized pion and kaon fragmentation functions, employing the nonlocal chiral-quark model, which manifests the nonlocal interactions between the quarks and pseudoscalar mesons, considering the explicit flavor-SU(3)-symmetry breaking in terms of the current-quark masses. Moreover, we study the quark-distribution functions, derived from the fragmentation ones with the Drell-Yan-Levi relation. Numerical results are evaluated to higher Q^2 by the DGLAP evolution and compared with the empirical data. The ratios between the relevant valance quark-distribution functions are also discussed. It turns out that the present results are in relatively good agreement with available data and other theoretical estimations.

[1]S. -i. Nam and C. -W. Kao, Phys. Rev. D **85**, 034023 (2012);
[2] S. -i. Nam and C. -W. Kao, Phys. Rev. D **85**, 094023 (2012).

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Probing two-photon exchange with OLYMPUS

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Two-photon exchange is believed to be responsible for the discrepancies in the proton electric to magnetic form factor ratio found with the Rosenbluth and polarization transfer methods. If this explanation is correct, one expects significant differences in the lepton-proton cross sections between positrons and electrons. The OLYMPUS experiment at DESY in Hamburg, Germany was designed to measure the ratio of unpolarized positron-proton and electron-proton elastic scattering cross sections over a wide kinematic range with high precision, in order to quantify the effect of two-photon exchange. The experiment used intense beams of electrons and positrons stored in the DORIS ring at 2.0 GeV interacting with an internal windowless hydrogen gas target. The current status of OLYMPUS will be discussed.

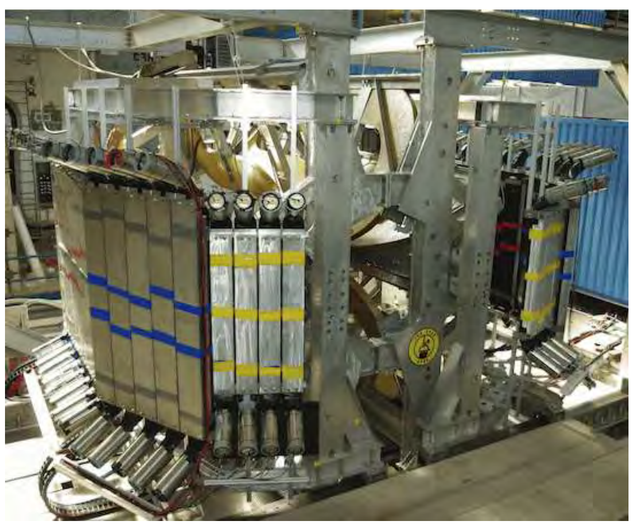

Figure 1: *The OLYMPUS setup shortly before the installation into the DORIS ring in July 2011.*

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Muon Elastic Scattering with MUSE at PSI

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The proton radius puzzle is the disagreement between the much more precise radius determined from muonic hydrogen spectroscopy and the numerous atomic hydrogen and electron scattering determinations. The puzzle has several possible resolutions, including beyond standard model physics, missing conventional physics, and errors or underestimated uncertainties in the extraction of the radius from the data. New experiments are needed to confirm and / or resolve the puzzle. The **MU**on **S**cattering **E**xperiment (MUSE) recently approved at PSI has been designed to help resolve the puzzle by measuring the radius in a way not yet done. Similar to electron scattering, the radius will be extracted from the observed change of the charge form factor with momentum transfer. The experiment uses the πM1 beamline to provide a mixed secondary muon and electron (and pion) beam of either positive or negative charge. The comparison of muon and electron scattering measured simultaneously determines the consistency of the form factors in the two cases with high precision. Comparison of yields from both charge signs will at the same time disentangle the effect of two-photon exchange. The proton charge radius can be extracted from each set of scattering data. The physics case and status of MUSE will be discussed.

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(1+1) QCD & Transverse Quark States in a Flux Tube

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In order to describe the dynamics of particle production and hadron spectrum in a flux tube, we start with an action integral in QCD_4 in (3+1) dimensional space-time with a confining scalar transverse interaction. Under the dominance of longitudinal motion of the valence quark-antiquark pair, the four dimensional space-time QCD_4 can be compactified into QCD_2 in (1+1) dimensional space-time [1]. The obtained action integral is found to govern massive fermion and gluon fields, with a relation between the coupling constant g_{2D} in QCD_2 and g_{4D} in QCD_4. The contribution to the quark and gluon masses due to the flux tube are derived. The coupling constants and the masses depend crucially on the excitation of the partons in the transverse degrees of freedom. The spectrum of transverse degrees of freedom in the flux tube are studied in detail. On basis of the obtained quark eigenstates of a tube, the gluon and fermion masses as well as 2D coupling constants, g_{2D}, are calculated. The relation of the obtained gluon mass to the spectrum of observable hadrons will be considered.

[1] A. V. Koshelkin and C. Y. Wong, Phys. Rev. **D86**, 125026 (2012).

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Exotic Hybrid Meson Spectroscopy with the GlueX detector at JLab

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The GlueX experiment[1] is scheduled to begin taking data in 2015. The goal is to discover evidence for the existence of exotic hybrid mesons and to map out their spectrum in the light quark sector. Hybrid mesons, and in particular exotic hybrid mesons, provide the ideal laboratory for testing QCD in the confinement regime since these mesons explicitly manifest the gluonic degrees of freedom. Recent theoretical developments using Lattice QCD [2] predict exotic hybrid states in a mass range accessible using the newly upgraded 12GeV electron accelerator at Jefferson Lab. The experiment will use 9 GeV linearly polarized photons produced via coherent bremsstrahlung to produce the exotic hybrids. The decay products will be detected in the solenoid-based GlueX detector which is currently under construction at Jefferson Lab. The status of the GlueX experiment including detector parameters will be presented along with theoretical motivation for the experiment.

[1] JLab Experiment E12-06-102. *Mapping the Spectrum of Light Quark Mesons and Gluonic Excitations with Linearly Polarized Photons*. http://www.jlab.org/exp_prog/proposals/06/PR12-06-102.pdf.

[2] Jozef Dudek. The lightest hybrid meson supermultiplet in QCD. *Physical Review D*, 84(7), 2011.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Longitudinal and transverse spin structure of the nucleon at COMPASS

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COMPASS is a multi-purpose xed target experiment at CERNs Super Proton Synchrotron, dedicated to the study of the structure of the nucleon.
In 2010 and 2011, high statistics data for inclusive and semi-inclusive deep inelastic scattering have been collected using polarized muons on a polarized NH3 target, at energies from 160 to 200 GeV/c. Measurements of asymmetries in longitudinal spin configuration give access to the quark and gluon polarization, key inputs to describe the nucleon spin. The new data obtained at COMPASS in 2011 improve significantly the statistical accuracy at low xBjorken, and help to better constrain the quark helicities in this region. High precision asymmetry measurements in 2010 in transverse spin configuration have allowed to refine the knowledge of several Transverse Momentum Dependent distribution functions, amongst of which Collins and Sivers, and their study gives valuable input to the yet poorly known quark transverse spin distributions.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spin Density Matrix Elements in exclusive production of ω and ϕ mesons at Hermes

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Spin-density matrix elements SDMEs describe the distribution of final spin states of the produced vector meson. These elements depend on helicity amplitudes for the angle and momentum dependent transition process between initial spin states of the virtual photon and final spin of the produced vector meson. The values of SDMEs can serve to establish the hierarchy of the helicity amplitudes that are used to describe exclusive vector-meson production. They are also used to test s-chanel helicity conservation (SCHC) hypothesis and to investigate contribution of unnatural parity exchange mechanism in vector meson production.

The HERMES experiment at DESY has measured SDMEs for both ω and ϕ mesons. The omega meson is observed in the following process with decay branching ratio $Br = 89.1\%$:

$$e + p \to e' + p' + \omega(\to \pi^+\pi^-\pi^0(\to (2\gamma)),$$

while the ϕ meson is studied in the reaction :

$$e + p \to e' + p' + \phi(\to K^+K^-)$$

The angular distribution in exclusive electroproduction of vector mesons on unpolarized targets depends on 23 SDMEs, 15 which do not depend on beam polarization and 8 which depend on beam polarization. The 23 SDMEs were extracted by fitting experimental angular distribution with theoretical angular distribution by likelihood method.

These SDMEs have been determined for exclusive ω meson production on Hydrogen and Deuterium targets, at HERMES kinematic region of $1.0 < Q^2 < 10.0$ GeV^2 and $2.0 < W < 6.3$ GeV and $-t^/ < 0.2$ GeV^2 and for ϕ meson at $1.0 < Q^2 < 7.0$ GeV^2 and $2.0 < W < 6.3$ GeV and $-t^/ < 0.4$GeV^2.

The presentation of the extracted SDMEs is based on the hierarchy of Natural Parity Exchange (NPE) helicity amplitudes:

$$|T_{00}| \sim |T_{11}| \gg |T_{01}| > |T_{10}| \gtrsim |T_{1-1}|.$$

No s-channel Helicity Conservation (SCHC) violation is observed in exclusive ω and ϕ meson production. The comparison of ω and ρ^0 SDMEs and of the calculated value u1:

$$u_1 \equiv 1 - r^{04}_{00} + 2r^{04}_{1-1} - 2r^1_{11} - 2r^1_{1-1},$$

indicates large contribution of unnatural parity exchange amplitudes in exclusive ω meson production.

Transverse spin and transverse momentum structure of the nucleon from the COMPASS experiment

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The description of the partonic structure of the nucleon is one of the central problems of hadronic physics. In recent years considerable theoretical and experimental progress has been made and the relevance of the quark transverse spin and transverse momentum has been clearly assessed. In the present theoretical framework, eight transverse momentum dependent parton distribution functions (TMD PDFs) are required at leading twist for each quark flavor. They describe all possible correlations between the transverse momentum and spin of the quarks, and the spin of the nucleon. When integrating over the quark transverse momentum five of these functions vanish, while three of them give the well known number, helicity and transversity distribution functions. Among these last three functions, the transversity distribution, which is the analogous of the helicity PDFs in the case of transversely polarized nucleons, was thoroughly studied only in the 90s and experimentally it is the least known one. On the experimental side, several complementary processes are being, and will be, studied to access the TMD PDFs, namely transversely polarized hard proton-proton scattering, Drell-Yan processes, and semi-inclusive deeply inelastic lepton scattering (SIDIS). This last channel is today the major source of information. It allows to access easily convolutions of the different TMD PDFs and fragmentation functions via high statistic measurements of asymmetries in the azimuthal distributions of the final state hadrons. Also, using different (p, d, or n) targets and identifying the final state hadrons, one can separate the contributions of the quarks of different flavor. The clear non-zero spin asymmetries recently measured in SIDIS off transversely polarized targets by both HERMES at DESY and COMPASS at CERN at different beam energies, can be described quite well with the present formalism, and thus give much more confidence in the overall picture.

COMPASS (COmmon Muon and Proton Apparatus for Structure and Spectroscopy) is a fixed target experiment at the CERN SPS taking data since 2002. An important part of the experimental programme consists in the study of the nucleon structure and SIDIS data have been collected using a 160 GeV longitudinally polarized muon beam and longitudinally or transversely polarized proton (NH_3) and deuteron (^{6}LiD) targets. From all these data several measurements related to the transverse structure of the nucleon have been performed, and the aim of this talk is to give a summary of the COMPASS contribution to the field. A selection of the results on the azimuthal asymmetries measured from the data collected with transversely polarized targets is presented, with particular focus on the most recent measurements from the data collected in 2007 and 2010 with the proton target. These results exhibit clear signals for the Collins asymmetry, interpreted as a convolution of a non-zero transversity PDF and Collins fragmentation function, and for the Sivers asymmetry which is related to the Sivers function, the most famous and discussed of the TMD PDFs. The comparison with the HERMES results at lower beam energy gives insights in the Q^2 evolution of the TMD functions. The data collected with the ^{6}LiD target, suitably mixed up to cancel possible target polarization effects, have also been analysed to search for the azimuthal modulations in the production of hadrons which are expected to be present in the SIDIS cross-section. The azimuthal hadron asymmetries, which are related to the Boer-Mulders TMD PDF, show strong and somewhat puzzling kinematical dependencies. Finally, complementary information on the parton transverse momentum distribution has been obtained from the measured multiplicities of the final state hadrons.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Monte Carlo Approach to Fragmentation Functions Using the NJL-jet Model

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The recently developed NJL-jet model provides a microscopic description of both favored and unfavored quark fragmentation functions within a Monte Carlo framework based on the the original quark-cascade hadronization picture of Field and Feynman. The effective chiral quark model of Nambu and Jona-Lasinio (NJL) has been used to calculate the input elementary hadron emission probabilities. The model has been first used to calculate the unpolarized integrated fragmentation functions of light and strange quarks to pions, kaons, vector mesons, nucleons, and antinucleons, where the employment of the Monte Carlo approach allowed for a detailed analysis of various aspects of the hadronization process, such as the influence of the vector meson production and decays on the measured pseudoscalar meson fragmentations. The model has also been extended to calculate the transverse momentum dependent fragmentation functions of both unpolarized and transversely polarized quarks, as well as the quark dihadron fragmentation functions. Moreover, using these results along with NJL calculated transverse momentum dependent unpolarized quark distributions in the nucleon, the Monte Carlo generator has been expanded to describe the unpolarized semi- inclusive deep inelastic scattering (SIDIS), and it has been used to determine the average transverse momentum squared of the produced hadrons measured in SIDIS.

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Studies of the transverse structure of the nucleon at Jefferson Laboratory

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Since the earliest measurements in the '70, hadronic physics deals with a number of surprising phenomena that cannot be explained in the framework of perturbative QCD. Examples are the small fraction of the proton spin carried by the valence quark spins, the persistence at high energies of single spin asymmetries and azimuthal asymmetries in unpolarized processes. It is now believed that the answer to these questions may come from the transverse motion of partons inside the nucleon, which is encoded in the Transverse Momentum Dependent (TMD) Parton Distribution Functions. Among the large variety of processes that can be described in terms of TMDs, a major role is played by Semi-Inclusive Deep Inelastic Scattering (SIDIS) reactions, in which, together with the scattered electron, one or more hadrons are detected in the final state. Single and Double Spin Asymmetries are the experimental observables sensitive to TMDs. The identification of the final hadrons allows the tagging of the quark involved in the reaction at the parton level, and then the flavor separation of the relevant TMDs. SIDIS reactions are studied at Jefferson Laboratories since many years and are one of the main items in the physics program after the upgrade of the CEBAF accelerator. The large amount of new data that will be available in few years calls for the implementation of new tools, such as multidimensional analyses and refined techniques of TMDs extraction from the experimental asymmetries.

In this talk, the more recent results obtained at 6 GeV will be shown and the future measurements will be discussed.

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Pentaquark Θ^+ search experiment at J-PARC

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Exotic hadrons, such as a pentaquark, provide a good place to examine low energy QCD dynamics in the non-perturbative regime. The pentaquark Θ^+ is an exotic light baryon with strangeness $S = +1$ and has a distinctive feature of a quite narrow width. The existence of the Θ^+, however, is still controversial. In order to have a definite answer to the existence of Θ^+, an experiment having a higher sensitivity has been long awaited.

The J-PARC E19 experiment aims to search for the Θ^+ pentaquark with high-resolution and high-statistics via the $\pi^- p \to K^- X$ reaction. Thanks to a good momentum resolution of both the K1.8 beam and the SKS spectrometers, a missing-mass resolution of less than 2 MeV/c^2 was achieved. As the result of the first run with 1.92 GeV/c beam, no peak structure corresponding to the Θ^+ mass was observed [1]. The upper limit of the differential cross section averaged over the scattering angle from 2° to 15° in the laboratory frame was derived to be 0.26 μb/sr in the mass region of 1.51 - 1.55 GeV/c^2. Combining the result with a theoretical calculation using the effective Lagrangian approach [2], the upper limit of the Θ^+ decay width was estimated to be 0.72 and 3.1 MeV/c^2 for $J^P_\Theta = 1/2^+$ and $1/2^-$, respectively. We have also carried out the second run in 2012 at 2.0 GeV/c, which is the maximum momentum of the K1.8 beam line. Increase of the incident momentum makes it possible to reach a higher sensitivity and then to have a stronger constraint on the decay width of Θ^+. Again no peak structure has been observed, but more stringent limit will be provided. In this contribution, the final result of the E19 experiment will be reported.

[1] K. Shirotori et al., Phys. Rev. Lett. **109**, 132002 (2012).
[2] T. Hyodo, A. Hosaka and M. Oka, Prog. Theor. Phys. **128**, 523 (2012).

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

On timelike and spacelike deeply virtual Compton scattering at next to leading order

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We study timelike and spacelike virtual Compton scattering in the generalized Bjorken scaling regime at next to leading order in the strong coupling constant, in the medium energy range which will be studied intensely at JLab12 and in the COMPASS-II experiment at CERN. We show that the Born amplitudes get sizeable $O(\alpha_s)$ corrections and, even at moderate energies, the gluonic contributions are by no means negligible. We stress that the timelike and spacelike cases are complementary and that their difference deserves much special attention.

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DVCS at HERMES

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Deeply Virtual Compton Scattering (DVCS) is currently one of the most promising processes that provides information about the structure of the nucleon in the framework of Generalized Parton Distributions. During last years the Deeply Virtual Compton Scattering process was extensively studied at HERMES, through measurements of cross section asymmetries. To the virtue of unique experimental conditions, HERMES has collected wealth of data on scattering a longitudinally polarized lepton (electron/positron) beam off unpolarized, longitudinally and transversely polarized hydrogen targets, as well as off an unpolarized and longitudinally polarized deuterium targets. Collected data allow to measure a complete set of asymmetries with respect to beam charge, beam helicity and target polarization alone and also with respect to their different combinations. The variety of measured asymmetries provide sensitivity to real and/or imaginary parts of different combination of Compton Form Factors, and can be used to constrain different Generalized Parton Distributions.

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Looking for meson molecules in B decays

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We discuss the possibility of observing a loosely bound molecular state in a B three-body hadronic decay. In particular we use the QCD sum rules approach to study a $\eta' - \pi$ molecular current. We consider an isovector-scalar $I^G J^{PC} = 1^- \, 0^{++}$ molecular current and we use the two-point and three-point functions to study the mass and decay width of such state. We consider the contributions of condensates up to dimension six and we work at leading order in α_s. We obtain a mass around 1.1 GeV, consistent with a loosely bound state, and a $\eta' - \pi \to K^+ K^-$ decay width around 10 MeV.

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Nuclear structure functions and parton densities at the LHeC

The LHeC Study Group

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The proposed Large Hadron-electron Collider at CERN will collide 60 GeV electrons and positrons against the LHC beams, providing center-of-mass energies around 1 TeV per nucleon. It will give access to a completely unexplored region of small x and high Q^2 which, in the nuclear case, exceeds those already explored in DIS experiments by four orders of magnitude. After a brief introduction, the possibilities for extracting the nuclear structure functions F_2^A and F_L^A and their flavour decompositions at the LHeC, will be discussed. The inclusion of such measurements in the extraction of parton densities within DGLAP global analysis, resulting in a dramatic reduction of present uncertainties for sea quark and gluon nuclear densities at small x, will also be presented.

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Predicting a 2.9 GeV $Df_0(980)$ molecular state

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A D-like meson resonance with mass around 2.9 GeV has been found in the $DK\bar{K}$ system using two independent and different model calculations based on: (1) QCD sum rules and (2) solution of Fadeev equations with input interactions obtained from effective field theories built by considering both chiral and heavy quark symmetries. The QCD sum rules have been used to study the $D_{s^*0}(2317)\bar{K}$ and $Df_0(980)$ molecular currents. A resonance of mass 2.877 GeV is found with the $Df_0(980)$ current. Although a state in the $D_{s^*0}(2317)\bar{K}$ current is also obtained, with mass around 2.9 GeV, the coupling of this state is found to be two times weaker than the one formed in $Df_0(980)$. On the other hand, few-body equations are solved for the $DK\bar{K}$ system and its coupled channels with the input t-matrices obtained by solving Bethe-Salpeter equations for the DK, $D\bar{K}$ and $K\bar{K}$ subsystems. In this study a D-like meson with mass 2.890 GeV and full width $\sim$ 55 MeV is found to get dynamically generated when $DK\bar{K}$ gets reorganized as $Df_0(980)$. However, no clear signal appears for the $D_{s^*0}(2317)\bar{K}$ configuration. The striking similarity between the results obtained in the two different models indicates strongly towards the existence of a $Df_0(980)$ molecule with mass nearly 2.9 GeV.

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Nucleon spectral function from QCD sum rules with MEM

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The QCD sum rule method is a powerful tool for studying hadron properties directly from QCD. In this method, the correlation function of an interpolating field operator coupled to the hadron of interest, which can be calculated in the deep Euclidean region by the operator product expansion (OPE), is related to the hadronic spectral function. The non-perturbative contributions in the correlation function are expressed by vacuum condensates such as the chiral condensate. In the traditional analysis, it is necessary to assume some specific functional form, such as the "pole + continuum"-ansatz, for the spectral function. On the other hand, our approach with the help of the Maximum Entropy Method (MEM) is able to extract the spectral function without assuming a specific form. The method has been successfully applied to the rho meson sum rule [1] and the nucleon sum rule [2] in vacuum.

We have applied this analysis method of QCD sum rules to the spectral function of the nucleon and its negative parity excited states in vacuum [3]. We construct the parity projected nucleon sum rules including the first order α_s corrections by using a phase-rotated Gaussian kernel. Both the positive and negative parity spectral function of the nucleon are extracted after the MEM is applied to the sum rule. The obtained spectral functions are shown in Fig. 1. We find that the difference between the positive and negative parity spectral function is mainly caused by the chiral condensate. Applying this method, an investigation of the nucleon spectral function in nuclear medium is now in progress.

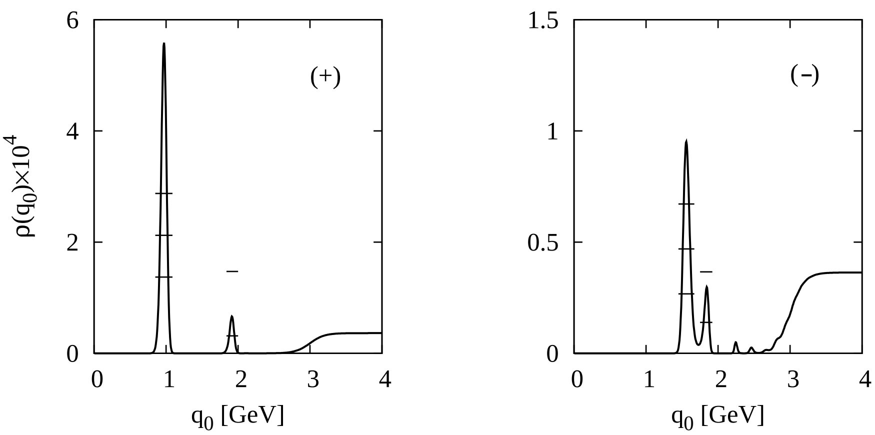

Figure 1: *The positive (left) and negative parity (right) spectral functions extracted from MEM analyses of the OPE data. The parity of the corresponding spectral functions is shown on the top right corner of each figure.*

[1] P. Gubler and M. Oka, Prog. Theor. Phys. **124**, 995 (2010).
[2] K. Ohtani, P. Gubler and M. Oka, Eur. Phys. J. A **47**, 114 (2011).
[3] K. Ohtani, P. Gubler and M. Oka, arXiv:1209.1463 [hep-ph].

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Selected TMD results from Hermes

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After fifty years of investigations, the nucleon structure is still far from being understood and continues to represent a unique test bench for QCD. Despite the enormous progresses achieved in five decades of Deep-Inelastic Scattering (DIS) experiments, a number of crucial open questions are still on the carpet and subject of intense theoretical and experimental studies. In the last decade, Semi-Inclusive DIS (SIDIS) was established as a unique tool for the study of the non-collinear structure of nucleons, involving the parton transverse momentum p_T as an additional degree of freedom. Requiring the detection of at least one final state hadron in coincidence with the scattered lepton, it opened the way not only to measure the chiral-odd transversity distribution, the last missing leading-twist collinear parton distribution function (PDF), but also to a variety of new p_T-dependent PDFs, known as TMDs. Describing correlations between the quark transverse momentum and the quark or the nucleon spin (i.e. spin-orbit correlations), TMDs account for a number of intriguing effects observed in polarized and unpolarized reactions, and allow for a 3-dimensional description of the nucleon in momentum space (nucleon tomography). Furthermore, they could provide insights into the yet unmeasured quark orbital angular momentum. At leading-twist eight TMDs enter the SIDIS cross section in conjunction with a fragmentation function (FF) [1]. Among them, particularly interesting is the Boer-Mulders function [2], describing the correlation between the quark transverse momentum and the quark spin in an unpolarized nucleon. At HERMES this distribution function is probed through the study of $\cos(2\phi)$ and $\cos(\phi)$ azimuthal modulations in the distribution of hadrons produced in unpolarized SIDIS of electrons and positrons off hydrogen and deuterium targets [3]. Amplitudes of these modulations for identified pions and kaons, recently extracted also in a four-dimensional kinematic space, will be reported. Another intriguing TMD is the so-called worm-gear g_{1T} function [4], 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. Preliminary HERMES results on A_{LT} double-spin asymmetries will be presented. Finally, a quick overview of selected A_{UT} single-spin asymmetries, such as the leading-twist $\sin(3\phi-\phi_S)$ and the subleading-twist $\sin(\phi_S)$ azimuthal modulations, will be shown.

[1] A. Bacchetta et al., JHEP 02, 093 (2007).
[2] D. Boer and P. J. Mulders, Phys. Rev. D57, 5780 (1998).
[3] A. Airapetian et al (HERMES), Phys. Rev. D (in press), arXiv:1204.4161.
[4] A.M. Kotzinian and P. J. Mulders, Phys. Rev. D54, 1229 (1996).

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Strangeness Vector and Axial-Vector Form Factors of the Nucleon

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A revised global fit of electroweak ep and νp elastic scattering data has been performed, with the goal of determining the strange quark contribution to the vector and axial-vector form factors of the nucleon in the momentum-transfer range $0 < Q^2 < 1$ GeV^2. The two vector (electric and magnetic) form factors $G_E^s(Q^2)$ and $G_M^s(Q^2)$ are strongly constrained by ep elastic scattering data, while the major source of information on the axial-vector form factor $G_A^s(Q^2)$ is νp scattering data. Combining the two kinds of data into a single global fit makes possible additional precision in the determination of these form factors, and provides a unique way to determine the strange quark contribution to the nucleon spin, ΔS, independently of leptonic deep-inelastic scattering. The fit makes use of data from the BNL-E734, SAMPLE, HAPPEx, G0, and PVA4 experiments; we will also compare the result of the fit with recent data from MiniBooNE, and anticipate how this fit can be improved when new data from MicroBooNE become available.

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Production and Dalitz decays of baryon resonances in p+p interactions at E_{kin}=1.25 and 3.5 GeV beam energy with HADES

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HADES is a versatile magnetic spectrometer installed at GSI Darmstadt on SIS18 [1]. Thanks to its high acceptance, powerful particle (p/K/π/e) identification and very good mass resolution (2-3% for dielectrons in the light vector meson mass range) it allows to study both hadron and rare dilepton production in *N+N*, *p+A*, *A+A* collisions an a few AGeV beam energy range.

Nucleon-nucleon reactions play in this context a special role providing a reference for *p+A* and *A+A* collisions. Exclusive channels ppe^+e^- and $ppe^+e^-\gamma$ as well as $pp\pi^0$ and $pn\pi^+$ were studied in proton+proton collisions providing stringent constraints on various theoretical models. A main emphasis was placed on understanding of vector mesons (ω/ρ) and baryon resonances production and their dielectron decays.

In p+p @ 1.25 GeV two major sources, π^0 and Δ, are expected to play a dominant role in e^+e^- production. In particular, for the first time the Δ resonance has been reconstructed exclusively via the pe^+e^- decay channel. This is an important issue since the branching ratio of electromagnetic Δ Dalitz decay had not been measured before. The resonance cross section has been determined from hadronic channels (one pion production) by means of the PWA (Partial Wave Analysis) [2].

At higher kinetic energy (3.5 GeV) dielectron pair production is determined by Dalitz decays of neutral mesons (π^0, η, ω) and baryonic resonances (N*, Δ) and, in the high mass region, by two body decays of ω / ρ. At this beam energy the e^+e^- invariant mass distribution appears to be sensitive to the structure of the baryon resonance electromagnetic transition form-factors in the time like-region [3, 4] . In the presentation we compare our data to various theoretical predictions [5, 6, 7, 8].

[1] G. Agakishiev et al., Eur. Phys. J. A41 (2009) 243;
[2] A.V. Anisovich et al., Eur Phys. J. A34 (2007) 129;
[3] Q. Wan, F. Iachello, Int. J. Mod. Phys. A20 (2005) 1846;
[4] G. Ramalho, M.T. Pena, Phys. Rev. D85 (2012) 113014;
[5] S. Teis et al., Z. Phys. A356 (1997) 421;
[6] B.V. Martemyanov et al., Phys.Rev. C84 (2011) 047601;
[7] J. Weil et al., arXiv:1203.3557 [nucl-th];
[8] S.A. Bass et al., Prog. Part. Nucl. Phys. 41 (1998) 225.

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The Proton Form Factor Ratio Measurements at Jefferson Lab

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The ratio of the proton form factors, G_{Ep}/G_{Mp}, has been measured from Q^2 of 0.5 GeV^2 to 8.5 GeV^2, at the Jefferson Laboratory, using the polarization transfer method. This ratio is extracted directly from the measured ratio of the transverse and longitudinal polarization components of the recoiling proton in elastic electron-proton scattering. The discovery that the proton form factor ratio measured in these experiments decreases approximately linearly with four-momentum transfer, Q^2, for values above $\approx$ 1 GeV^2, is one of the most significant results to come out of JLab. These results have had a large impact on progress in hadronic physics; and have required a significant rethinking of nucleon structure. 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}. There is an approved experiment at JLab, **GEP(V)**, to continue the ratio measurements to 12 GeV^2. 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 nucleon form factors.

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New Extraction of the Flavor Decomposition of the Nucleon Electromagnetic Form Factors

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Recent measurements of the neutron's electric to magnetic form factors ratio, $R_n = \mu_n G_E^n/G_M^n$, up to 3.4 (GeV/c)^2 [1] combined with previous $R_p = \mu_p G_E^p/G_M^p$ measurements in the same Q^2 range [2] allowed, for the first time, a detailed comparison of the ratios F_2^n/F_1^n and F_2^p/F_1^p as well as a separation of the up- and down-quark contributions to the form factors at high Q^2 [1,3]. The earlier analysis [3] combined measurements (and the associated uncertainties) of R_n with parametrizations of the other form factors [4], neglecting their uncertainties. Our new analysis [5] expands on the original by including two-photon exchange (TPE) corrections to the proton form factors [6], adding the recent CLAS G_M^n extractions [7], and accounting for the uncertainties in all of the nucleon form factors. With these modifications, we extract a complete set of flavor-separated form factors up to $Q^2 \approx 4.0$ (GeV/c)^2 and compare these results to recent calculations of the up- and down-quark contributions. In this talk we will present our results, emphasizing the TPE correction procedure used to extract the proton form factors and uncertainties, as well as the updated extraction of the magnetic form factor of the neutron. We find large differences between the up- and down-quark contributions to the nucleon form factors suggesting significant flavor dependence in the charge and magnetization distributions. In addition, the strong linear falloff in G_E^p/G_M^p with Q^2 is not present in either the up- and down-quark contributions, and arises in the proton due to a cancellation between the up- and down-quark contributions. Also, our results suggest that the down-quark contributions to the Dirac and Pauli form factors deviate from the $1/Q^4$ scaling, with small differences observed between the Q^2 dependence in F_1 and F_2 for both the up- and down-quark contributions. Moreover, the up and down quarks yield very different contributions to G_E/G_M (and F_2/F_1), and the down-quark contribution to this ratio is not well reproduced by any of the models. Finally, the tension between the CLAS and older G_M^n extractions suggests the need for improved measurements near 1.0 (GeV/c)^2 to obtain reliable information on the down-quark contributions at low Q^2.

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[1] S. Riordan, *et al.*, Phys. Rev. Lett. **105**, 262302 (2010);
[2] V. Punjabi *et al.*, Phys. Rev. C **71**, 055202 (2005); O. Gayou *et al.*, Phys. Rev. C **64**, 038202 (2001);
[3] G. D. Cates, C.W. de Jager, S. Riordan, and B.Wojtsekhowski, Phys. Rev. Lett. **106**, 252003 (2011);
[4] J. J. Kelly, Phys. Rev. C **70**, 068202 (2004);
[5] I. A. Qattan and J. Arrington, Phys. Rev. C **86**, 065210 (2012);
[6] I. A. Qattan, A. Alsaad, and J. Arrington, Phys. Rev. C **84**, 054317 (2011);
[7] J. Lachniet *et al.* (CLAS Collaboration), Phys. Rev. Lett. **102**, 192001 (2009).

Polarized Drell-Yan studies at COMPASS

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The COMPASS experiment at CERN will start in 2014 a new series of measurements using a pion beam at 190 GeV/c impinging in a transversely polarized ammonia target. The study of the polarized Drell-Yan process will provide an insight of the transverse momentum dependent parton distribution functions (TMDs), which is complementary to their extraction from semi-inclusive deep inelastic scattering (SIDIS). The results of the latter, performed in COMPASS since 2002, had a very important impact in the present knowledge of TMDs. Theory predicts that the Sivers and Boer-Mulders TMDs have opposite sign when accessed from SIDIS or Drell-Yan, due to their naive time-reversal odd nature. This sign change experimental observation is considered an essential test of the TMD approach. Such check will be possible in COMPASS after one year of data-taking.

The experimental aspects of the Drell-Yan measurement in COMPASS will be discussed. The set-up optimization was driven by the results of several beam tests performed in the last years, using a prototype hadron absorber, and testing the detectors response to the high intensity hadron beam, as well as the dimuon trigger concept. The expected event rates and statistical errors of the azimuthal asymmetries will be presented.

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Search for permanent Electric Dipole Moments

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The Standard Model (SM) of Particle Physics 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. Direct searches of proton and deuteron EDMs bear the potential to reach sensitivities beyond 10^{-29} e·cm.

The research environment at Jülich coupled to the strong experienced groups of scientists and engineers from Jülich, RWTH-Aachen, Brookhaven National Lab, Ferrara University, and many other institutions, provides an ideal starting point for charged particle EDM searches. The talk will emphasize 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.

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The incompleteness of complete pseudo-scalar meson photoproduction

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Thanks to recent technological advances in producing high-quality polarized beams and in developing polarized nucleon targets, it becomes possible to measure a sufficiently large amount of single- and double-polarization observables in pion and kaon photoproduction from the proton. As a result, a status of complete quantum mechanical information of meson photoproduction comes within reach. Measurements are complete whenever they enable one to determine unambiguously all amplitudes of the underlying reaction process. We consider pseudo-scalar meson photoproduction from the proton for which complete measurements involve a determination of single- and double-polarization observables. Over the years possible strategies to turn complete measurements into efficient tools to learn about the underlying dynamics of meson photoproduction have been proposed. Complications arise due to the non-negligible uncertainties in real data. In addition, there are issues related to the fact that some observables are linked to bilinear products of amplitudes by means of nonlinear equations.

We propose to use normalized transversity amplitudes $\{a_i\}$ to perform an amplitude analysis of the single- and double- polarization observables. Normalized transversity amplitudes provide complete information of the process under study, after determining the total cross section. The corresponding polarization observables can be expressed in terms of linear and non-linear equations of bilinear products of the $\{a_i\}$. For a given kinematic setting determined by the meson angle and the photon energy, the $\{a_i\}$ are fully determined by six real numbers conveniently expressed as three moduli and three relative phases.

We have conducted studies with pseudo-data generated by a realistic model for $\gamma p \rightarrow K^+\Lambda$ to illustrate the effectiveness of the proposed strategy. The adopted model for $\gamma p \rightarrow K^+\Lambda$ is the Regge-plus-Resonance approach in its most recent version RPR-2011 [1,2]. The model has a Reggeized t-channel background and the s-channel resonances $S_{11}(1650)$, $F_{15}(1680)$, $P_{13}(1720)$, $D_{13}(1900)$, $P_{13}(1900)$, $P_{11}(1900)$, and $F_{15}(2000)$. The RPR provides a low-parameter framework with predictive power for K^+ and K^0 photoproduction on the proton and the neutron [3].

As a conclusion of our studies with $\gamma p \rightarrow K^+\Lambda$ pseudo-data, we find that single-polarization observables are effective in determining the moduli of the amplitudes in a transversity basis. Determining the relative phases of the amplitudes from the double-polarization experimental results is far less evident.

[1] L. De Cruz, J. Ryckebusch, T. Vrancx, P. Vancraeyveld, Phys. Rev. C 86, 015212 (2012)
[2] L. De Cruz, T. Vrancx, P. Vancraeyveld, J. Ryckebusch, Phys. Rev. Lett. 108, 182002 (2012)
[3] P. Vancraeyveld, L. De Cruz, J. Ryckebusch, T. Vrancx, Nucl. Phys. A897, 42 (2013).

A systematic study of longitudinal and transverse helicity amplidutes in the hypercentral Constituent Quark Model

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We report in a systematic way the predictions (*) of the non-relativistic hypercentral Constituent Quark model for the electromagnetic excitations of baryon resonances. The model contains three parameters, which are determined by fitting the mass spectrum of non strange baryon reosnances. The longitudinal and transverse helicity amplitudes are then calculated with no free parameters for fourteen resonances, both for proton and neutron and compared to a large number of experimental data.The calculations lead to an overall fair description of data, specially in the medium Q^2 range, where quark degrees of freedom are expected to dominate.

(*)E. Santopinto, M.M. Giannini, Phys. Rev. C86, 065202 (2012)

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Valence and sea quarks in nucleon structure

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An overview of Constituent Quark Models for baryons and mesons and their results will be presented and discussed. The emerging need for the introduction of higher Fock components, *i.e.* the unquenching of the quark model [1], will be discussed and the explicit results obtained for the magnetic moments, the angular momentum of the proton and the flavor asymmetry [2] will be presented.

[1] R. Bijker and E. Santopinto, Phys. Rev. C 80, 065210 (2009);
[2] E. Santopinto and R. Bijker, Phys. Rev. C **82**, 062202(R) (2010).

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Short-range correlations of partons, and 3D nucleon structure

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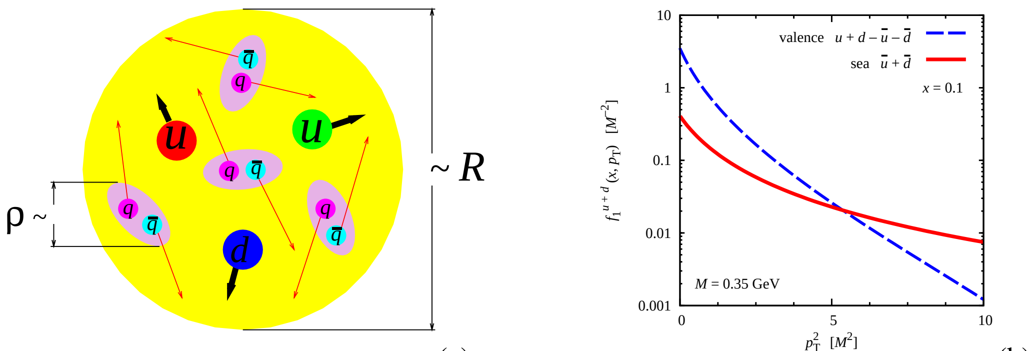
The dynamical breaking of chiral symmetry in QCD is caused by nonperturbative interactions on a scale $\rho \sim 0.3\,\text{fm}$ much smaller than the hadronic size $R \sim 1\,\text{fm}$, Fig. 1a. The non-perturbative short-distance scale ρ has critical impact on the intrinsic transverse momentum distributions of partons and their correlations at a low normalization point $\mu \sim \rho^{-1}$ [1]. This phenomenon is studied in an effective description of the low-energy strong interaction dynamics based on chiral constituent quark and Goldstone boson degrees of freedom, which is justified in the large-N_c limit of QCD. The nucleon is described in terms of constituent quarks and antiquarks bound in a self-consistent chiral field. This framework is realized in the chiral quark-soliton model, and allows to calculate the distributions of constituent quarks and antiquarks which can be identified with QCD parton distribution functions at low normalization scale μ [2].

The p_T distribution of valence quarks is roughly of Gaussian shape with a width of $p_T^2 \sim R^{-2}$. The sea quark distributions exhibit a power-like tail $\sim 1/p_T^2$ extending parametrically far beyond that up to the chiral symmetry-breaking scale ρ^{-1}, see Fig. 2b. The mechanism generating these high-momentum tails is due to short-range correlations between sea quarks in the nucleon's light-cone wave function [1]. This is in analogy to NN correlations in nuclei. The nucleon wave function contains correlated pairs of transverse size $\rho \ll R$ with σ- and π-like quantum numbers, whose internal wave functions become identical for $R^{-2} \ll p_T^2 \sim \rho^{-2}$. These features represent genuine, model-independent effects of dynamical chiral symmetry breaking on the nucleon's partonic structure. The results have important implications for the description of transverse momentum distributions of particles produced in hard scattering processes. The predicted nonperturbative parton correlations could be observed in particle correlations between the current and target fragmentation regions of DIS [1].



(a) (b)

Figure 1: *(a) The non-perturbative scales governing the nucleon structure: $R \sim 1\,fm$ sets the hadron size and describes valence quark effects, $\rho \ll R$ characterizes short-range correlations and determines the dynamics of sea quarks. (b) The distinct behavior of p_T-distributions of valence and sea quarks [1].*

[1] P. Schweitzer, M. Strikman and C. Weiss, JHEP **1301**, 163 (2013) [arXiv:1210.1267 [hep-ph]].
[2] D. Diakonov, V. Petrov, P. Pobylitsa, M. V. Polyakov and C. Weiss, Nucl. Phys. B **480**, 341 (1996).

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Determination of E and G observables in η photo-production on the CLAS Frozen Spin Target (FROST)

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Polarization observables are vital for disentangling the overlapping resonances in the baryon spectrum. Extensive data have been collected at Jefferson Lab in Hall B with circularly and linearly polarized tagged photon beam incident on longitudinally polarized protons provided by the Frozen Spin Target (FROST). The presentation will focus on η photo-production, which acts as an "isospin filter" by restricting possible proton excitations for one step processes to be isospin 1/2 resonances. Preliminary results for the double-polarization observables E and G will be presented. There are currently no data on these in the world database for η photo-production.

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Dynamically generated resonances from the vector meson-baryon octet interaction

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In Refs [1, 2], the interaction of vector mesons with the octet and decuplet of baryons has been studied in the framework of the local hidden gauge formalism using a coupling channels unitary approach. The scattering amplitudes in coupled channels develop poles which can be associated with some known baryon resonances, and can also give some predictions for new ones. However, only the $t-$ channel diagram between the vector meson and the baryon has been calculated under the low energy approximation, while the contributions from $s-$ channel and $u-$ channel interactions between vector mesons and baryons are neglected. In the article of Ref. [3], the authors study the interaction between vector meson and baryon octet with the similar method to that used in Refs [1, 2], but the diagrams of $s-$, $t-$,$u-$ channels and a contact interaction term originating from a tensor interaction Lagrangian are all calculated in a non-relativistic approximation. Recently, I have recalculated the diagrams of $s-$, $t-$,$u-$ channels and contact terms of the vector meson-baryon octet interaction using a relativistic coupling channels approach. Moreover, the contribution of the tensor interaction between vector mesons and baryons is also discussed. In this talk, I will show some different results on this problem.

[1] E. Oset and A. Ramos, Eur. Phys. J. A **44**, 445 (2010) [arXiv:0905.0973 [hep-ph]].
[2] S. Sarkar, B. -X. Sun, E. Oset and M. J. Vicente Vacas, Eur. Phys. J. A **44**, 431 (2010) [arXiv:0902.3150 [hep-ph]].
[3] K. P. Khemchandani, H. Kaneko, H. Nagahiro and A. Hosaka, Phys. Rev. D **83**, 114041 (2011) [arXiv:1104.0307 [hep-ph]].

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Hadron spectroscopy and the search for gluonic excitations

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I will discuss progress towards analysis of hadron spectrum emerging from present high statistics experiments at COMPASS and BESIII, and future analysis plans for GlueX and CLAS12 at JLab. The first appearance of hadronic physics at the forefront of particle physics occurred 40 years ago. A great deal of understanding of hadron reaction theory has been achieved and various methods for data analysis and interpretation have been proposed. Nowadays hadrons fall into domain of interest of both nuclear and particle physics. I will focus on discussing connections between the phenomenological S-matrix based analyst methods and current developments in QCD specifically in the context of searches for exotic hadrons, e.g. hadrons with gluonic excitations.

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The GPD program at COMPASS

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Hard exclusive electro- and muoproduction of photons and mesons on nucleons has played an important role in studies of strong interactions and recently gained renewed interest as it allows access to generalised parton distributions (GPDs). The GPDs provide a novel and comprehensive description of the partonic structure of the nucleon and contain a wealth of new information. For instance the GPDs give a description of the nucleon as an extended object, referred to as 3-dimensional nucleon tomography, and give access to the orbital angular momentum of quarks. Deeply Virtual Compton Scattering (DVCS) is the most straightforward process to access quarks GPDs, while mesons due to the different quark contents and the quantum numbers can be used to access GPDs for specific quark flavours and gluons.

In this talk we will summarize measurements of exclusive vector meson production performed by the COMPASS Collaboration. In particular, recent results on the azimuthal asymmetries for meson production on the transversely polarized protons and deuterons will be presented. One of this asymmetries is sensitive to the 'elusive' GPDs E for quarks, which are related to the orbital angular momentum. Also, planned measurements of exclusive photon and meson production, which are a part of the approved COMPASS-II proposal, will be discussed. The main aim of this measurements is access to the GPDs H, which are related to 3-dimensional nucleon tomography. Results on DVCS and exclusive π^0 production from the 2009 test run, where experimental setup with liquid hydrogen target and recoil proton detector was used, will be also presented.

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Low-lying pseudoscalar and vector mesons and their dynamics

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In [1,2] a chiral Lagrangian has been suggested which is inspired by the framework of effective field theories and contains the low-mass pseudoscalar and vector mesons as dynamical degrees of freedom. While the pseudoscalar mesons are special because of their character as Goldstone bosons of chiral symmetry breaking, vector mesons are important for any process which couples electromagnetism to hadrons (vector-meson dominance). The application of the Lagrangian to various decays and form factors [3,2] is reviewed. Such in part rare decays are presently investigated by high-precision experiments like WASA, KLOE, HADES and MAMI. Comparison to experimental data will be provided where possible and predictions for yet unmeasured rare decays will be presented.

[1] M.F.M. Lutz, S. Leupold, On the radiative decays of light vector and axial-vector mesons, Nucl. Phys. A813 (2008) 96-170.

[2] C. Terschluesen, S. Leupold, M.F.M. Lutz, Electromagnetic transitions in an effective chiral Lagrangian with the eta' and light vector mesons, arXiv:1204.4125 [hep-ph].

[3] C. Terschluesen, S. Leupold, Electromagnetic transition form factors of light vector mesons, Phys. Lett. B691 (2010) 191-201.

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Electromagnetic proton form factors: perspectives for PANDA

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Electromagnetic form factors are fundamental properties of composite particles. The contribution foreseen at PANDA in this field will be illustrated. The PANDA collaboration gathers today more than 500 physicists, from 62 laboratories in 16 countries. The PANDA experiment [1] will make use of the high intensity antiproton beams, with momentum from 1.5 to 15 GeV/c, produced by the FAIR facility in Darmstadt [2], to study annihilation reactions with very large accuracy. The physics goals are broad, ranging from charmonium spectroscopy, search for hybrids and glueballs, hypernuclei, to light and heavy meson production. In this contribution we will focus to leptonic final channels which contain the information on time-like form factors. We will show the expected precision on the electric and magnetic form factors, which are expected to be measured separately for the first time in a broad kinematical range. The detection of an accompanying pion will allow to investigate the "unphysical region", also for the first time. At present, precise data from polarized electron-proton elastic scattering on one side [3], and from electron positron annihilation into proton antiproton with initial state radiation on the other side [4], show surprising features, questioning the traditional view on the internal structure of the nucleon: the behavior of the electric and magnetic distributions inside the nucleon are shown to be different, nucleons seem to behave as point-like particles at threshold [5], time-like proton form factors are twice as large as the corresponding space-like ones. We will discuss the experimental facts, the proposed interpretations [6] and show the potentiality contained in the future data from annihilation reactions at PANDA in view of a global description of the electromagnetic structure of the proton.

[1] http://www.gsi.de/PANDA; The Panda physics program arXiv:0903.3905 [hep-ex];
[2] http://www.gsi.de/FAIR;
[3] A. J. R. Puckett *et al.*, Phys. Rev. Lett. 104, 242301 (2010);
[4] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. D 73, 012005 (2006);
[5] R. Baldini *et al.*, Eur. Phys. J. A 39, 315 (2009);
[6] E.A. Kuraev *et al.*, Phys. Lett. B 712, 240 (2012).

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A nonextensive statistical model for the nucleon structure function

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During the eights and nineties many statistical-thermodynamical models [1,2,3,4 and references therein] were proposed to describe the nucleon structure functions. Most of these models describe the compound quarks and gluons inside the nucleon as a Fermi-Bose gas respectively, confined in a MIT bag [5]. Some interesting features of the nucleons are obtained by these models, like the asymmetries of the antiquarks sea, the ratio between the neutron and proton structure function F_2^n/F_2^p , and the spin dependent structure functions for instance.

Recently, the nonextensive statistical mechanics, proposed by Tsallis [6] has been considered to explain some features of nuclear collisions, for instance, the proton-proton, central Pb-Pb and others [7,8]; also the pion-nucleon experimental phase shift shows evidence of nonextensive quantum statistics [9]. Applications on quark-gluon plasma was studied by Walton and Rafelski [10] Lavagno et al. [11] and for the stelar media Lavagno and Pigato [12]. The theoretical foundation of these works is the fact of the nonextensive statistical mechanics can be considered as an appropriate basis to deal with physical system with strong correlation dynamics systems, long range interactions and memory effects . On the experimental side, the observations on relativistic heavy ions collisions may reflect nonextensive statistical behavior.

The quarks inside a nucleon have strong correlation dynamics and, according to some confining model used, long range interactions. For this reason, we intend to show a study about the features of a structure function of the nucleon based on the principles of the nonextensive thermodynamics. Since the usual thermodynamics is a special case of the nonextensive (if $q = 1$) the focus is to show the effects of change the q values around $q \to 1$.

[1] R.P. Bickerstaff, J.T.Londergan; Phys.Rev. D **42** (1990) 3621.
[2] V. Devanathan, S. Karthiyayini, K.Ganesamurthy , Modern Physics Letters A **9** ,(1991) 3455
[3] V. Devanathan, J.S. McCarthy, Modern Physics Letters A, **11** (1996) 147.
[4] R.S. Bhalerao, Phys. Lett. B **380** (1996) 1
[5] A.Chodos et al., Phys.Rev. D **9** (1974) 3471.
[6] C. Tsallis, Possible generalization of Boltzmann-Gibbs statistics, J. Stat. Phys. 52, 479-487 (1988). E.M.F. Curado and C. Tsallis, Generalized statistical mechanics: connection with thermodynamics, J. Phys. A 24, L69-72 (1991); Corrigenda: 24, 3187 (1991) and 25, 1019 (1992).
[7] G. Wilk and Z. Wlodarczyk, in Classical and Quantum Complexity and Nonextensive Thermodynamics, eds. P. Grigolini, C. Tsallis and B.J. West, Chaos, Solitons and Fractals , Number 3, 547 (Pergamon-Elsevier, Amsterdam, 2002);
[8] C.E. Aguiar and T. Kodama, Physica A **320** (2003), 371.
[9] D.B. Ion and M.L.D. Ion, Phys. Rev. Lett. 81, 5714 (1998)
[10] D.B. Walton and J. Rafelski, Phys. Rev. Lett. 84, 31 (2000).
[11] A. Lavagno, D. Pigato, P. Quarati, J. Phys. G: Nucl. Part. Phys.37:115102, 2010.
[12] A. Lavagno, D. Pigato; Eur. Phys. J. A 47 (2011) 52

Determination of T and F observables in η photoproduction on the CLAS Frozen Spin Target (FROST)

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Polarization observables are an important tool for understanding and clarifying baryon resonance spectra. Recently, experiments were conducted at Jefferson Lab using a polarized photon beam incident on a polarized frozen spin target (FROST). We present preliminary data of the T and F asymmetries for η photoproduction from the proton, along with comparisons to theoretical predictions. The data used in the present analysis were taken during the second running period of FROST using the CLAS detector at Jefferson Lab, which utilized transversely polarized protons in a butanol target and an incident tagged photon energy between 0.62 and 2.93 GeV. The T asymmetry is the observable related to transverse target polarization and the F asymmetry is a double-polarization observable that requires circular beam polarization in addition to transverse target polarization.

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Constraining ΔG at Low-x with Double Longitudinal Spin Asymmetries at Forward Rapidity at PHENIX

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Understanding the gluon polarization, ΔG, and specifically its Bjorken-x dependence, $\Delta g(x)$, within a proton is central to understanding the proton spin structure. The two quantities are related simply by $\Delta\text{G} = \int_0^1 \Delta g(x) dx$. While $\Delta g(x)$ is constrained at moderate and high values of x, $x > 0.05$, we are just beginning to glimpse the low-x behavior where there are large uncertainties. This results in a large overall uncertainty in ΔG. The Muon Piston Calorimeter (MPC) at forward rapidity, $3.1 < |\eta| < 3.9$, including its recently commissioned trigger upgrade, were designed to greatly increase our sensitivity to gluons as low as $x \sim 10^{-3}$ through asymmetric collisions with valence quarks. Experimentally, the MPC measures the double helicity asymmetry in electromagnetic clusters, A_{LL}, between same sign and opposite sign helicity proton collisions. For single clusters, we have sensitivity down to $x \sim 10^{-2}$. We will present the results of this measurement at $\sqrt{s} = 200$ GeV and the status of the $\sqrt{s} = 500$ GeV measurement, both from 2009 data. Finally, we will discuss the outlook for how these double longitudinal asymmetries will constrain $\Delta g(x)$. Currently, the systematic and statistical uncertainties are comparable in size. While we anticipate a very large data set from 2013 data, we will also briefly discuss our efforts to reduce the systematic errors, which will play an important role in ultimately constraining ΔG.

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From Hadronic to Partonic Degrees of Freedom in Nuclear Physics

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Understanding hadron interactions and nuclear structure in terms of the fundamental degrees of freedom of QCD has been a long-standing problem in nuclear physics. At high enough energies, quarks interact weakly, allowing perturbative calculations to be performed. Alternatively, in the low-energy, or confinement regime, a solution of QCD is very difficult to be obtained. At these energies, effective field theories, that use hadronic degrees of freedom, are quite successful in describing hadron interactions and nuclear structure. It is quite unclear what are the underlying dynamics and the fundamental degrees of freedom in the largely unexplored transition region between the meson-nucleon and the quark-gluon descriptions of nuclear physics.

In this talk I will present experimental studies of photonuclear reactions that help to address two key questions in modern nuclear physics: is there a clear transition between the hadronic and partonic descriptions of nuclei and how do we describe this transition? Deuteron photodisintegration has been a benchmark process for the investigation of the role of quarks and gluons in nuclear reactions. Polarization observables play a crucial role in accessing features of the underlying dynamics. Specifically, the beam-spin asymmetry, Σ, is predicted to have a large sensitivity to reaction mechanisms. Results obtained with the CLAS detector at the Thomas Jefferson Laboratory, along with a brief overview of the experimental setup and analysis procedure will be presented. These results apply stringent constraints to the available theoretical predictions and provide the information needed to better understand the process of deuteron photodisintegration in the transition region.

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