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SUMMARY OF WORKING GROUP F
SPIN PHYSICS

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In working group F results on spin physics were presented from experiments ranging from low energy elastic electron scattering to pp collisons at $\sqrt{s} = 200$ GeV. All aspects of the nucleon structure were covered experimentally and theoretically – unpolarised, longitudinally polarised, and transversely polarised quark distributions. In addition, some results relevant for the extraction of generalised parton distributions were discussed.

1 Introduction

Spin physics – both experimental and theoretical studies – is presently a very active research field. The new experimental studies presented during the conference show either high precision results in the continuation of the inclusive measurements which started at SLAC in the seventies [1], or deal with observables in semi-inclusive or exclusive measurements – fields which are accessed experimentally only since a few years.

Until recently polarised DIS played the dominant role in the investigation of the spin structure of the nucleon by measuring asymmetries and spin structure functions, g_1 and g_2, in the scattering of polarised electrons or muons on polarised protons and neutrons [2]. Interpretation of these data is usually done in terms of NLO perturbative QCD analyses to determine the helicity dependent parton distribution functions, $\Delta q_i(x, Q^2)$ and $\Delta g(x, Q^2)$. Additional information on the flavour decomposition is obtained from semi-inclusive DIS.

The gluon contribution Δg is only poorly determined in these analyses and thus requires dedicated measurements, e.g. using the photon-gluon-fusion process in DIS or prompt photon production in pp-collisions.

The low Q^2 and low W region of the spin structure functions, which was basically unknown up to now, is now investigated in great detail at JLAB. With these data quark-hadron-duality [3] can be studied in detail also for spin structure functions.

To complete the picture of the nucleon knowledge on transverse quark distributions, $\delta q_i(x, Q^2)$, is required. Measurements are going on to determine the transversity distribution, $h_1(x)$. As $h_1(x)$ is a chirally odd quantity, it is not accessible in inclusive scattering, but only in semi-inclusive experiments measuring single spin asymmetries on transversely polarised targets. This allows to measure the product of $h_1(x)$ with a chirally odd fragmentation function [4], e.g. the Collins fragmentation function [5] which is unknown, too. Information on these fragmentation functions can be obtained from the analysis of e^+e^--collider experiments. Alternatively, transversity can be studied in pion production in collisions of transversely polarised protons.

To build up the spin of the nucleon, orbital angular momentum of the constituents is required in addition to quark and gluon helicities. According to Ji's sumrule [6] the total angular momentum of quarks may be accessed by measuring the generalised parton distributions, E and H, in exclusive reactions like deeply virtual Compton scattering.

Given all these developments the presentations submitted to the spin physics working group were divided into the following sessions:

1. Inclusive measurements and parton distribution functions.
2. Gluon polarisation.
3. Single spin asymmetries and transversity.
4. Exclusive reactions and generalised parton distribution functions.
5. Future plans.

The session on item 1 was shared partially with working group A for the talks on global PDFs and the session on item 4 with working group B for the talks on DVCS and vector meson production.

2 Experiments

During the sessions results were presented from a large variety of experiments, ranging from low energy elastic scattering and DIS fixed target experiments to lepton and hadron colliders.

Fixed target measurements in the DIS range were performed by

- HERMES at DESY using the 27 GeV electron or positron beam together with their internal polarised proton and deuteron target,
- SMC at CERN using the 190 GeV muon beam with polarised deuterated butanol or ammonia,
- COMPASS at CERN using 160 GeV muons and a polarised ^{6}LiD target.

Experiments with electron energies up to 6 GeV are performed at JLAB. Hall A experiments cover the transition region between DIS and the resonance region, while CLAS in Hall B and RSS in Hall C investigate the resonance region. In addition, results were presented from parity violating elastic electron scattering experiments at Bates, MAMI and JLAB using polarised electron beams and unpolarised H and D targets.

Contributions from collider experiments to the field of spin physics currently stem from RHIC and the KEK B-factory. At BELLE investigations are going on to determine fragmentation functions like the Collins fragmentation function which will help to extract the transversity distribution from semi-inclusive DIS. At RHIC, PHENIX and STAR took data with transversely and longitudinally polarised 200

GeV proton beams to extract information on transversity and the gluon distribution via pion production, jet production and later, when higher luminosity and polarisation will be available, direct photons and W-production.

3 Inclusive asymmetries and parton distributions functions

Currently most new results on inclusive spin measurements come from JLAB experiments studying the resonance region and the approach to the DIS region. Here, data were shown from:

- E-94-110 on a high statistics measurement of $R = \sigma_{\mathrm{L}}/\sigma_{\mathrm{T}}$ in the resonance region,
- E-01-006 (RSS) on the asymmetries $A_{\parallel}$ and $A_{\perp}$ in the resonance region,
- CLAS EG1 on g_1^{p} and g_1^{d} in a large kinematic range starting at the resonance region,
- E-99-117 with high statistics A_1^{n} at high x,
- E-97-103 with high statistics g_2^{n} at $x \approx 0.2$.

The experiment E-94-110 presented by R. Ent [7] was performed in hall C using both spectrometers, HRS and SOS. Several beam energies between 1.2 and 6 GeV were used to extract R and F_2 from scattering on a 4 cm liquid hydrogen target. Two analysis methods were followed: The first one used the standard Rosenbluth like separation by determining the ϵ dependence of the cross section. The other used a simultaneous fit of F_2 and R. Results from both methods agree very well and yield very precise results for R. R is large at low Q and high W and a clear resonant behaviour is observed at low W.

Similar measurements in polarised scattering on $^{15}\mathrm{NH}_3$ and $^{15}\mathrm{ND}_3$ were performed by E-01-006 (RSS) in hall C presented by M. Khandaker [8]. Here, the first measurement of $A_{\parallel}$ and $A_{\perp}$ in the resonance region was done using the high resolution spectrometer (HRS). The data cover a range in W from 0.8 GeV to 2 GeV with $Q^2 \approx 1.3$ GeV^2. Preliminary results for the asymmetries were shown. Due to the high statistics also an accurate extraction of the neutron asymmetry should be possible. The CLAS EG1 measurements in hall B concentrated on longitudinally polarised $^{15}\mathrm{NH}_3$ and $^{15}\mathrm{ND}_3$ targets only, but cover a large range in Q^2 (0.05 to 5 GeV^2) and W (from the elastic peak to 3 GeV) due to the large acceptance detector. Data were taken at several beam energies. Preliminary result for g_1^{p} and g_1^{d} from data at two energies were presented. As in the RSS results clear resonance structures are visible on all low W data. In addition, the Q^2 dependence of the first integral of g_1 was determined allowing to investigate the approach to the GDH sum rule.

All resonance data (polarised and unpolarised) were used to study quark-hadron duality. While it seems to hold for F_2 and F_{L} even at quite low Q^2, the situation is more complex for spin structure functions. In general, duality seems to be a working concept down to $Q^2 \approx 1.5$ GeV^2, but there are clear violations in the region of the Δ resonance.

The hall A experiments E-99-117 and E-97-103 in the DIS region were presented by K. Kramer [10]. The results on $A_1(x)$ [9] for high x (0.3 – 0.6) obtained with a polarised ^{3}He target clearly show that A_1 turns positive at high x, in qualitative agreement with most models. In the continuation of the experiment measurements were done at 3 energies to obtain a high statistics measurement of $g_2^{\mathrm{n}}(Q^2)$ at $x \approx 0.2$. The results show a deviation from g_2^{WW} for the lower Q^2 points of 2–3 σ, hinting at a twist-3 effect. The determination of the systematic errors in still in progress.

COMPASS measured inclusive asymmetries parallel to their data taking for Δg with a longitudinally polarised ^{6}LiD target (presented by M. Leberig [11]). The data from one year of data taking were shown for $Q^2 > 1$ GeV^2. The results for A_1^{d} have an accuracy at low x comparable to the previous SMC results and show good agreement with them. With the additional data already collected by COMPASS the errors will improve considerably. These data will also be used to study semi-inclusive asymmetries to do a flavour separation.

More news on specific quark flavours were presented by F. Maas [12]. He gave an overview on experiments measuring parity violating elastic electron scattering. The tiny asymmetries are sensitive to the γ/Z interference contribution to the cross section. This allows to determine the strange quark contribution to the nucleon vector form factors, provided the Pauli and Dirac form factors of the proton and neutron are known with some precision. Experiments were performed by SAMPLE at MIT-Bates using the 200 MeV polarised electron beam, by Happex and G0 at JLAB and by A4 at the 855 MeV Microtron MAMI. For all these measurements a large effort was put into the control of systematics which could produce false asymmetries.

From their measurements with hydrogen and deuterium SAMPLE found a value for the strangeness magnetic form factor at $Q^2 = 0.1$ GeV^2 which is compatible with 0. Using proton targets HAPPEX and A4 measured a combination of the strangeness electric and magnetic form factors. These data hint to a non-zero strangeness contribution to the nucleon form factors. To make a full separation further data taking at different kinematics is being prepared.

The second part of this session covered new theoretical developments:

The Asymmetry Analysis Collaboration concentrates on the determination of polarised PDFs and their uncertainties. The new AAC analysis was presented by S. Kumano [13]. In addition to the data used for the previous AAC00 PDFs, the recent SLAC E155 g_1^{p} data were included resulting in improved parton distributions, not only for valence quarks, but especially for the sea quarks. The polarised gluon distribution is quite small but has very large uncertainties. To investigate the correlation between antiquarks and gluons further, the analysis was repeated using $\Delta g = 0$. Within uncertainties the AAC03 parametrisation agrees with other analyses.

A. Sidorov [14] pointed to the fact, that the present polarised DIS data all are at relatively low Q^2. In such a case non-perturbative higher twist contributions cannot be neglected generally. Depending on the method used in the QCD analysis these contributions can be important. If the analysis is done with results for A_1 or g_1/F_1, obtained with phenomenological parametrisations of F_2 and R, sizeable higher twist contributions in A_1 may be present. Using an additive higher twist term for g_1 improves the fits considerably. Especially for the neutron the contributions seem to be non-negligible. This analysis underlines once more the importance of a consistent treatment of all quantities used in such a perturbative QCD analysis.

Another approach was discussed by P. Zavada [15]. He described a model prediction for the spin structure of the nucleon starting from a system of quasi free fermions on mass shell with total angular momentum 1/2 using a consistent covariant approach. This Ansatz results in relations between spin structure functions reflecting well known sum rules. In addition, it is possible to relate the distributions in the rest frame to g_1 and F_2 using SU(6) symmetry, so that g_1, g_2 and their moments can be calculated from the well known unpolarised valence distributions. The results agree quite well with experimental measurements. In a similar way the model can be extended to yield predictions for the unknown transversity distribution.

4 Gluon polarisation

All the inclusive analyses result in rather large uncertainties for the gluon polarisation, thus direct measurements are urgently needed.

In DIS the gluon distribution is accessible via the photon gluon fusion process. Therefore, few years ago several activities were started to determine Δg either from open charm production or from high p_{T} hadron pairs. After an initial extraction of hadron pairs asymmetries in quasi real photo production from HERMES [16], new results were presented from SMC and COMPASS.

K. Kowalik [17] presented the analysis of SMC data taken with a 190 GeV muon beam and polarised proton (ammonia) and deuteron (butanol) targets. Asymmetries were extracted for hadron pairs with large transverse momenta with respect to the virtual photon direction. Although this enhances the photon gluon fusion contribution to about 30% there are non-negligible backgrounds from the leading order process (photon absorption) and gluon radiation (QCD Compton). Due to a Q^2 cut of $Q^2 > 1$ GeV^2 resolved photon processes can be neglected. In the data selection a cut of $\Sigma p_{\mathrm{T}}^2 \geq 2.5$ GeV^2 was used. The final analysis included two methods, the standard one used a set of optimised cuts, whereas the second one made use of a neural network. From the measured asymmetries $A^{\mathrm{lN}\longrightarrow\mathrm{lhhX}}$ the gluon polarisation was extracted using background contributions estimated from Monte Carlo simulations with the LEPTO generator. The resulting value of $\Delta g/g = 0.20 \pm 0.28 \pm 0.10$ is dominated by statistical errors and is compatible with 0.

The measurement of the gluon polarisation is one of the main aims of the COMPASS experiment. The beam flux is a factor of 5 higher than for SMC and the hadron acceptance was much improved through the use of a 2 stage spectrometer. Particle identification (π/K/p separation) is done with the help of a RICH detector. Two methods to determine $\Delta g/g$ are used, either high p_{T} hadron pairs or open charm production.

In case of open charm production D^0 mesons have to be reconstructed. Due to the long solid state polarised target reconstruction of the D^0 decay vertices is not possible. They are reconstructed from the invariant mass distribution using e.g. the decay into a pion and a kaon. This method is hampered by the huge combinatorial background below the D^0 peak. Selecting D^* by adding a slow π suppresses much of the background. Here about 300 D^0 were selected in the 2002 data. From the measured asymmetry the gluon polarisation can be directly calculated. An error of 0.24 for the gluon polarisation is predicted for the data from 2002 to 2004.

The high p_{T} analysis closely follows the method developed by SMC except for the omission of the Q^2 cut. The resulting asymmetry is $A_{\mathrm{LL}}^{\gamma^* \mathrm{d}} = -0.065 \pm 0.36_{\mathrm{stat}} \pm 0.010_{\mathrm{syst}}$. Here the systematic error is still under investigation and includes up to now only studies on false asymmetries due to the target and the spectrometer. Extracting Δg from this asymmetries is more involved than for the SMC analysis. The use of all Q^2 events changes the background contributions, as resolved photons and vector meson exchange become more important. Assuming a PGF contribution of 25% an error of 0.05 can be achieved for Δg with the data from 2002 to 2004.

The gluon polarisation can also be measured in collider experiments using the polarised proton beams at RHIC. Measurements with longitudinally polarised protons were done in 2003 at PHENIX and STAR using 200 GeV protons with a polarisation of about 26%. The integrated luminosity was about 0.2 pb^{-1}.

S. Trentalange [21] reported on the STAR jet analysis. He gave a detailed account on the jet reconstruction in STAR using the solenoidal tracker and part of the electromagnetic calorimeter, thus mainly the central rapidity range is covered. An accurate measurement of the relative luminosity from bunch to bunch was obtained using a beam-beam counter. Work is still going on e.g. on the jet energy scale important for the measurement of the E_{T} dependence of the asymmetry. Here, E_{T} is the transverse jet energy. An error of about 0.03 for the asymmetry is expected for the full data sample.

The PHENIX analysis of π^0 asymmetries was presented by F. Bauer [20]. The π^0 reconstruction makes use of the electromagnetic calorimeter, which allows to access the central rapidity region. Background subtraction is done using sideband subtraction in the two photon invariant mass spectrum. The relative luminosity is determined with beam-beam counters as for STAR. The unpolarised π^0 production cross section was determined and showed good agreement with NLO perturbative QCD calculations for the whole range of transverse momenta. Additional systematic checks were performed for the asymmetry determination. The observed asymmetries in the p_{T} range between 1 and 4 GeV are small and slightly negative, but still compatible with 0.

A nice figure with the summary of the present status of the measurements of the gluon polarisation is given in [18].

The implications of the recent PHENIX results were discussed by S. Kretzer [19] and K. Sudoh [22]. It was pointed out, that several hard subprocesses like $\mathrm{gg} \to \mathrm{gg}$ and $\mathrm{qg} \to \mathrm{qg}$ contribute to π^0 production. But the processes most important at central rapidities have a positive partonic spin asymmetry. Therefore it was investigated in detail, how the sign and shape of Δg influence the π^0 asymmetry. Using a range of predictions from $\Delta g = 0$ to $\Delta g = \pm g$ results mostly in positive asymmetries due to the dominance of the $\mathrm{gg} \to \mathrm{gg}$ process. Only very special choices for the x dependence of Δg result in small negative asymmetries at higher values of p_{T} in contrast to the data, if they are taken at face values. This also illustrates the potential of the π^0 measurements to constrain Δg, when the data are improved with further measurements. Adding charged pion asymmetries will help to resolve the problems.

5 Single spin asymmetries and transversity

The transversity distribution is the only leading twist quark distribution for which no experimental data are available. As mentioned above it cannot be accessed in inclusive DIS as it is a chirally odd quantity. But in semi-inclusive DIS or proton-proton collisions it can couple to another chirally odd function, so that interesting single spin effects are expected.

In DIS transversity is investigated by measuring semi-inclusive target spin asymmetries on transversely polarised targets. Such measurements have been started at HERMES and COMPASS. Previously, related asymmetries were observed by HERMES [23] using longitudinally polarised targets exploiting the transverse component of the target spin relative to the virtual photon direction.

In leading twist there are two contributions to such a measurement. One stems from the transverse quark distributions and a chirally odd fragmentation function (Collins FF), the other originates in the Sivers distribution function combined with the normal unpolarised fragmentation function. The Sivers function is due to transverse momentum of the struck quark.

On transversely polarised targets the two contributions can be distinguished by calculating moments of the measured azimuthal asymmetries, $\sin(\phi - \phi_{\mathrm{S}})$ moments for the Sivers functions and $\sin(\phi + \phi_{\mathrm{S}})$ moments for the Collins functions. Here, ϕ is the angle between the lepton and the hadron plane and ϕ_{S} the angle between the transverse component of the target spin and the lepton plane.

COMPASS devotes about 20% of the data taking to measurements with transversely polarised ^{6}LiD target. Results from the first transverse run in 2002 were reported by H. Fischer [24]. In the analysis events with $Q^2 > 1$ GeV^2 and a leading hadron with $z > 0.25$ were selected. Hadron identification was performed using hadron calorimeters, but no π/K/p separation was attempted. To study resolutions and the contamination with non-leading hadrons, Monte Carlo simulations using the LEPTO generator were performed. The x and z dependence of the Collins moments was studied for positive and negative hadrons. All asymmetries are comparable with 0 within statistical errors. More data from 2002 and 2003 will improve the sensitivity by more than a factor of 2.

R. Seidl [25] presented results from HERMES using the data taken in 2002 with a transversely polarised hydrogen target. The asymmetry $A_{\mathrm{UT}}(\phi, \phi_{\mathrm{s}})$ was determined for $\pi^{\pm}$ identified with the RICH and for π^0. The Collins and Sivers asymmetries were fitted simultaneously. Sizeable Collins asymmetries were observed for π^+ and surprisingly also for π^-. A possible explanation of this effect is an unusual ratio of unfavoured to favoured Collins fragmentation functions of about -1. The Sivers moments were found to be positive for π^+ and π^0, while they are compatible with 0 for π^-. This might be related to non-vanishing orbital angular momenta of the quarks.

A discussion of the new HERMES result was given by P. Schweitzer [26]. The HERMES result on A_{UL} [23] triggered a lot of activities trying to describe the data as Collins asymmetries. As a result the Sivers contribution seemed to be small. In view of the new results these analyses have to be reconsidered. In addition the new Collins asymmetries cannot be described by the models at all. Taking also the slightly negative π^0 asymmetries into account it seems that the unfavoured fragmentation function is not only negative but larger than the favoured one. To resolve this paradox situation clearly more precise data are needed.

To proceed further with the interpretation of the data more experimental inputs would be helpful, e.g. an independent measurement of the Collins fragmentation function. Such a measurement can be done with e^+e^- collisions. Azimuthal asymmetries in pion production are sensitive to the Collins fragmentation function, while $\pi^+\pi^-$ pair production gives access to the interference fragmentation function. Some results were previously obtained from DELPHI data.

Here, M. Grosse-Perdekamp [27] presented the status of the BELLE analysis of off-resonance data at $\sqrt{s} = 10.52$ GeV. An integrated luminosity of 23 fb^{-1} is available. The analysis clearly demonstrates the high performance of BELLE for the observation of events with 2 jets (or 2 hadrons). The azimuthal asymmetries allow to extract the product of two Collins fragmentation functions. With the help of Monte Carlo simulations, acceptance corrections were determined and the reconstruction of the original quark momentum was investigated. An open problem is still the influence of gluon radiation which can generate false asymmetries. Thus, it is necessary to separate the Collins asymmetry from background asymmetries.

Another approach was proposed by A. Bacchetta [28]. He pointed to the problems of single hadron azimuthal asymmetries: As discussed above there are usually several contributions already in leading twist. If two hadron asymmetries are investigated there is only one leading twist contribution for A_{UT} sensitive to the transverse distribution and the interference fragmentation function. This might be an easier way to determine $h_1(x)$ than using single hadrons. In addition A_{LU} would allow to extract the distribution function $e(x)$.

More insight will also be gained from a measurement of single beam spin azimuthal asymmetries in pion production. The HERMES results were presented by E. Avetisyan [29]. Beam spin asymmetries receive different contributions from combinations of twist-2 and twist-3 distributions as for the single spin asymmetries discussed above. The data analysis for $\pi^\pm$ and π^0 follows a very similar procedure to other semi-inclusive analyses except for the strict z cut of $0.5 < z < 0.8$. This helps to minimize the contamination from target fragmentation and exclusive reactions. The x and p_{T} dependence of the moments were determined. For π^+ positive asymmetries of about 2% were observed, while π^0 and π^- are also positive but compatible with 0.

Transverse asymmetries were also studied in pp-collisions at RHIC. STAR and PHENIX took data with transversely polarised protons in 2002 and 2003 resulting in 0.8 pb^{-1}. Previous experiments with hadronic probes observed large transverse asymmetries which may be related to the Collins and Sivers effects.

The STAR results were presented by R. Fatemi [30]. For these measurements the polarisations were measured using a Coulomb nuclear interference polarimeter. Neutral pions were detected in the forward pion detector covering a rapidity range of $3.1 < \eta < 4.3$ and the x_{F} dependence of A_{N} was investigated. The asymmetries are of the order of 10 to 20% and increase with p_{T} and x_{F}. The mid-rapidity region was investigated by measuring charged particles in the STAR TPC. Here, the asymmetries are compatible with 0 within statistical errors. Dijet events may be helpful to isolate especially the Sivers effect, thus jet reconstruction was started in the TPC and the barrel electromagnetic calorimeter. With increased statistics and improved coverage with electromagnetic calorimetry there are good prospects to study especially the Sivers effect in detail.

In the PHENIX analysis reported by C. Aidala [31] data from the first polarised proton run in 2002 were used. The average polarisation was about 15% as was measured with the CNI polarimeter. Asymmetries were determined for neutral pions in the p_{T} range from 0.5 to 4.5 GeV and for charged pions from 0.5 to 2.5 GeV, with $x_{\mathrm{F}} \approx 0$. The asymmetries are small with a slight tendency to negative values. As this kinematic region is dominated by gluon scattering any contribution from transversity will be suppressed whereas a Sivers contribution is still possible. More data and further theoretical studies are needed in order to discuss the full implication of the results.

6 Exclusive reactions and generalised parton distribution functions

Access to generalised parton distributions (GPD) is obtained by measuring exclusive reactions in high energy lepton scattering experiments.

F. Ellinghaus [32] presented the HERMES analysis of deeply virtual Compton scattering which provides a theoretically clean access to the GPDs H and E which are needed in Ji's sumrule to determine the total angular momentum carried by quarks. Interference of DVCS and the Bethe-Heitler process results in azimuthal asymmetries. Beam charge asymmetries are sensitive to the real part of the DVCS amplitude, while beam spin asymmetries yield the imaginary part. Data stem from measurements with unpolarised or spin averaged hydrogen targets with electron and positron beams. Events with only one photon and one charged track (electron or positron) were selected. As the recoil proton was not detected, missing mass techniques were used to guarantee exclusivity. Both asymmetries show the expected $\cos(\phi)$ and $\sin(\phi)$ dependence, respectively. The data with unpolarised targets are mainly sensitive to H, but a measurement of the kinematic dependence is needed to distinguish between different models for H. This will be possible when all HERMES data are used for this analysis. To obtain sensitivity to E, measurements with transversely polarised targets are needed which are currently performed by HERMES. Including these data a first glimpse on the u-quark total angular momentum should be feasible.

A. Borissov [33] gave a review of the HERMES results on exclusive vector meson production using a hydrogen target. Similar to DVCS vector mesons provide access to the GPDs H and E. Vector mesons may be produced by two different mechanisms – either quark exchange or two gluon exchange. Using events with standard DIS kinematics exclusive ρ, ϕ and ω were selected and production cross sections determined. The results on $\sigma_{\mathrm{L}}/\sigma_{\mathrm{T}}$ indicate that SCHC for ρ and ϕ is violated on the 10% level. The longitudinal cross sections are sensitive to the production mechanism. ρ and ω production are dominated by quark exchange and ϕ production by two gluon exchange. Sizeable double spin asymmetries for ρ are observed and colour transparency is investigated. More data taken with the deuteron target are being analysed.

While vector meson production is sensitive to the unpolarised GPDs H and E pseudoscalar meson production allows to access the polarised GPDs $\tilde{H}$ and $\tilde{E}$. For example π^+ production at low t is dominated by the $\tilde{E}$ contribution.

Studies on hard exclusive pion production from HERMES were presented by C. Hadjidakis [35]. Data taken with polarised and unpolarised hydrogen targets from 1996 to 2000 were analysed. The selected events had typical DIS kinematics but only a scattered electron plus one π^+. As the recoil particle could not be detected the missing mass technique was used. But due to the limited experimental resolution no clear separation from the non-exclusive channels is possible. Thus, π^- production was used as a measure of the non-exclusive background. The acceptance was calculated using different models for GPDs and the Q^2 dependence of the cross section was extracted for 3 x bins. In addition, single spin asymmetries are being investigated. On transversely polarised targets interference terms between $\tilde{E}$ and $\tilde{H}$ may lead to large target single spin asymmetries. This will help to disentangle the two contributions. In 2002 – 2005 about 1000 exclusive π^+ are expected.

Additional information can be obtained from the exclusive electro production of $\pi^+\pi^-$ pairs. R. Fabbri [34] reported on the HERMES analysis using hydrogen and deuteron data. Events with DIS kinematics were selected and the missing mass technique was used to ensure exclusivity. Due to interference of P and S,D waves Legendre moments are useful tools. The $m_{\pi\pi}$ dependence of $\langle P_1 \rangle$ and $\langle P_3 \rangle$ is determined in the range from 0.4 to 1.4 GeV. The first Legendre moment shows a clear dependence on $m_{\pi\pi}$ due to the interference of the ρ meson with the non-resonant $\pi^+\pi^-$ S-wave. Also effects of the f mesons are observed. The results are compared to calculations using models for GPDs and can thus help to constrain generalised parton distribution functions.

E. Kuraev [36] reported on the calculation of 2π and 3π electro production on hydrogen. The aim is to study the interference of amplitudes with σ and ρ mesons decaying into 2 pions in the fragmentation region of the proton. This can be studied by measuring the charge asymmetry of 2π production. The predictions depend on the masses of the ρ and the σ. With an accuracy of 5% of the data the hypothesis that ρ and σ masses are degenerate could be tested seriously. In addition the $\gamma\gamma \to 3\pi$ anomaly was discussed.

A model for the generalized parton distributions of the pion was discussed by J.P. Lansberg [37]. Based on their method developed for the calculation of the diagonal distributions of the pion, the model was extended to GPDs. The calculated imaginary part of the off forward scattering amplitude is related to twist-two and twist-three GPDs. In addition, effects due to the finite size of the pion are taken into account. New relations between the GPDs were obtained.

7 Future

HERMES, COMPASS, STAR and PHENIX will continue to take data on a variety of physics questions. Measurements will be done with unpolarised targets and with longitudinal and transverse polarisation.

Also at JLAB there are several experiments that will continue with spin physics. One of them, E-03-109 (SANE) [8] will focus on the DIS high x region (0.3 – 0.8) for the proton and measure A_1 and g_2. For this experiment a new non-magnetic electron detector will be developed that will cover a large solid angle.

In the US, work continues to develop the physics and technical case for a high energy, high luminosity polarised electron-ion collider (EIC) as E. Kinney [38] reported. Collisions with polarised protons, deuterons, and 3He's would be used to make high precision measurements of the polarised structure functions of the nucleon by measuring inclusive, semi-inclusive, and exclusive reactions as a function of x and Q^2. At this time, two different accelerator proposals have emerged: eRHIC at BNL, where a new polarised electron (and possibly positron) accelerator would be combined with the existing polarised proton and heavy ion accelerator at RHIC. The other proposal, being developed by Jefferson Lab, is the electron-light ion collider (ELIC) which trades off high-energy and heavy ion beams for higher luminosity. The eRHIC group has already developed an initial design report for the accelerator. Recently, an internal long range plan for the US Dept of Energy listed this electron-ion collider program as a "must-do" project in the next 2 decades. The EIC collaboration continues to develop the detailed physics case, accelerator designs, and spectrometers for the interaction regions. The next essential milestone is a positive review in the next US long range planning (2005/2006).

8 Summary

At the previous DIS the spin sessions were clearly dominated by theoretical presentations, as many of the experiments just had taken new data and started to analyse them. This year, a wealth of results on many different questions in spin physics were presented. Among them were longitudinal asymmetries sensitive to the gluon polarisation and the first transverse asymmetries sensitive to the transverse quark distributions. The implication of the new data and their theoretical interpretation was lively discussed and was the subject of several contributions. Higher statistics experimental results are just around the corner and are eagerly awaited.

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