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"Future of DIS": Summary

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This is a summary of the activities of the "Future of DIS" session. The session was dominated by presentations on new and upcoming facilities to probe the structure of matter at present and higher energies, using different targets and projectiles with and without polarised beams. As such, the physics covered spanned a broad range, including R&D for possible future facilities and experiments, new physics at the high energy frontier, unfolding the proton and nuclear structure with unprecedented precision and unravelling their spin structure.

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1. Introduction

The "Future of DIS" session focused on three main areas of research in deep inelastic scattering physics. The first theme was the exploration of the high energy regime where new physics phenomena may be discovered. New facilities which would collide electrons with nucleons at higher energies than are presently possibly would be perfectly suited for the exploration of leptoquarks, searches for excited fermions, compositeness as well as Supersymmetry. Apart from the potential to discover new physics one could also study small x phenomena, the physics of high parton densities, diffraction, hard QCD and electroweak physics at energies previously unexplored. Here, the main facility discussed to reach this new kinematic regime is the Large Hadron Electron Collider (LHeC) machine at CERN.

Another major theme discussed was DIS with different targets and projectiles. Using nuclei, one can probe nuclear structure in DIS with unprecedented precision. Detailed analyses of the medium-modification of parton fragmentation functions can also be performed in collisions of leptons and nuclei. A related topic is the hadron formation which can be modified by the presence of the nuclear medium. A separate interesting field is deep inelastic scattering of neutrinos which can provide access to the structure function F_3. By selecting nuclear targets one can also analyse their influence on small x phenomena and reach the very high parton density regime with somewhat lower energies. Here, several proposals were discussed including an Electron Ion collider (EIC), LHeC with nuclei, MINERvA, E-906/Seaquest as well as proposals for new measurements at COMPASS.

The third main subject was spin. By performing DIS with polarised target beams one can gain access to valuable information about the nucleon spin structure. One can test the analogies between semi-inclusive DIS processes and the Drell-Yan process, extract the Sivers and Boer-Mulders functions and perform 3-dimensional detailed imaging of the nucleon. A variety of measurements of exclusive processes can give unique access to the generalised parton distributions and transverse momentum distributions. Here, two main facilities which have the potential to use polarised particles were the proposed EIC facility, to be built at BNL or JLAB, and new measurements at the existing COMPASS experiment.

The reader is encouraged to read the contributions from individual authors in these proceedings for more details than can be provided here.

2. LHeC

There were nine talks devoted to the LHeC proposal, including presentations on the machine, detector design, luminosity measurements and physics possibilities.

The LHeC is a proposed colliding beam facility at CERN. It will collide the existing LHC 7 TeV proton beam with a new electron beam. The operation of the LHeC will be simultaneous with the existing proton-proton LHC experiments. It also has the possibility of collisions of electrons with lead nuclei and perhaps deuterium.

John Jowett gave a presentation on the LHeC machine design status. There are currently two designs under consideration: a ring-ring scenario and a linac-ring scenario. In the ring-ring scenario the electrons will be accelerated in an additional ring installed in the tunnel. This scenario is similar

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to the HERA design, thus in principle is more conventional and familiar. Detailed studies of the design are currently being performed, in particular the integration of the additional ring with the existing LHC tunnel and the required bypasses around the ATLAS and CMS interaction regions. One of the main goals is to minimise the installation shutdown as the LHC will run for the highest possible integrated luminosity. This scenario offers high luminosity suitable for searches for new physics signatures. Electron energies are limited to about 70 GeV due to the injection energy and synchrotron radiation losses in the ring design. The power consumption limit is set to 100 MW.

An alternative design involves a linac-ring configuration where the electron beam would be accelerated in a new linac and would arrive tangentially to the interaction point with the LHC proton beam. This scenario has the advantage that it avoids most of the complications caused by interference with the existing LHC infrastructure. Currently three designs are under study, a pulsed linac with 60 GeV, an energy recovery linac with 60 GeV and a pulsed linac with 140 GeV. These designs allow for luminosities of 10^{32} cm^{-2}s^{-1} in the first and third case and 10^{33} cm^{-2}s^{-1} in the ERL case.

Peter Kostka discussed in detail the detector design for the LHeC. The design of the detector is of course determined by the setup of the machine itself, in particular the design of the interaction region, and by the physics motivation. The goal is to build on the successful experience with the H1/ZEUS detectors and study inclusive DIS with the highest possible precision and a large detector acceptance of at least $10-170$ degrees and beyond. For the LHeC, the aim is to improve on the energy and angular calibration and alignment precision with respect to H1 by a factor of two. This new acceptance window and the envisaged precision allows access to Higgs production and physics beyond the SM. For the low x and low Q^2 regime to be accessed, an acceptance for the scattered electron of $1-179$ degrees is mandatory. Precision hadronic calorimetry is required as well as detector acceptance for the hadrons down to a few degrees. Optimal Higgs and BSM searches also require the analysis of channels including heavy flavours in the final state, which requires the detector to perform efficient b and c tagging. For diffractive processes, it is essential to have the possibility to detect forward protons, neutrons and deuterons. In the current design study, two versions of the detector are considered, one with the largest possible angular acceptance down to 1 degree, optimised for low Q^2 - low x physics; the second version has an angular acceptance down to 10 degrees, optimised for physics at large Q^2. In the latter design, a strong focusing magnet system would allow luminosities of up to 10^{33} cm^{-2}s^{-1} to be achieved. The design of the detector is also determined by the dimensions of the beam pipe. In particular the large angular acceptance and minimisation of multiple scattering require very thin beam pipe designs. Sandwich designs for the beam pipe are under consideration, for example a Be/Al-Nomex-Be/Al configuration.

Sergey Levonian discussed the details of the luminosity measurement for the LHeC. As mentioned above, the nominal luminosity for the LHeC is $10^{31}-10^{33}$ cm^{-2}s^{-1} depending on the design scenario. The goal for the precision of the luminosity measurement is $\delta\mathscr{L}\sim 1\%$. Fast instantaneous luminosity monitoring is challenging, but a few options exist. For example, in the case of the ring-ring machine option, Bethe-Heitler photons can be detected using water Cherenkov counters integrated with a synchrotron radiation absorber. Some optimisation of the crossing angle is also required. The study of the design of the electron taggers for the luminosity measurement is also underway. Initial studies show that the placement of the electron taggers at 62 m is most promising due to the good acceptance, small synchrotron radiation and the available space. The electron tag-

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gers are also useful in enhancing the physics program. Good control of the electron beam optics at the interaction point is essential to monitor acceptances of the tunnel detectors at the level of 5 %.

The overview of QCD and electroweak measurements at the LHeC was presented by Olaf Behnke. The LHeC has the potential to completely unfold the partonic content of the proton: u, d, c, s, t, b and the gluon in an unprecedented kinematic range. This is based on inclusive neutral current and charged current cross section measurements, together with heavy quark identification. An almost complete picture of the proton structure, which the LHC experiments assume/need to know, will be accurately determined by deep inelastic scattering measurements at the LHeC. Detailed simulations of the constraints put on the parton distribution functions by the LHeC measurements were presented. The LHeC has enormous potential for constraining the parton distribution functions, especially the gluon and sea quark uncertainties in the small x regime. Simulated data for F_2^{charm} and F_2^{beauty} were presented which demonstrate the potential of the LHeC as a heavy flavour factory. These precise measurements could help understand the role and control the treatment of heavy masses in perturbative calculations.

Simulations of hard QCD processes were also presented. It was shown that the inclusive and jet data can allow the measurement of the strong coupling constant at the permille level. Predictions for jets in DIS and in photoproduction were also presented, showing that the LHeC can cover a range of jet energy scales up to several hundred GeV.

Analyses of the electroweak processes were also presented. Electroweak high precision standard model tests in the t-channel, especially for u and d quarks, are possible. Studies show that the LHeC could greatly improve the constraints on u and d-type quark couplings to Z_0, compared with HERA. This gives unprecedented sensitivity to possible deviations from the SM, for example in searches for leptophobic Z' models. Single top production is also an attractive channel at the LHeC and offers a sensitive test of the standard model parameters, in particular Wtb couplings.

As mentioned above, the physics analyses place very demanding requirements on the detector design. To have good control over the large $x > 0.1$ region it is necessary to have excellent forward hadronic calorimetry and control of the hadronic energy scale down to $\leq 1\%$. The heavy flavour physics program needs efficient charm and beauty tagging over a wide rapidity range.

The prospects of small x physics at the LHeC were presented in the talk by Nestor Armesto. There are many aspects of small x physics which could be enlightened with the help of the LHeC machine. One of the main outstanding questions are the implications of unitarity in QCD and its realisation in terms of partonic degrees of freedom. A related question is the behavior of QCD at large energies and the form of the hadronic wave function at small values of x. DIS electron-hadron scattering could also help us to understand the initial conditions for the creation of a dense medium in heavy-ion collisions.

With the nominal setup of 70 GeV electrons scattering on 7 TeV protons, the LHeC provides access to the x region of around 10^{-6} which greatly extends the range of the HERA collider. In the case of the scattering of nuclei, the gain is about four decades in x, thus constituting a completely new realm for studying nuclear structure. As mentioned previously, access to the small x region can only be guaranteed with a detector design incorporating the largest angular acceptance down to one degree.

Inclusive diffraction at the LHeC can be accessed in a much extended kinematic range. For example, at a value of $x_{IP} = 0.001$, the kinematic β range is extended by two orders of magnitude over HERA kinematics. Large values of diffractive masses are possible, which can include for example electroweak bosons or exotic particles. The relation between diffraction in electron-proton and nuclear shadowing for the case of the scattering on deuterons can also be investigated.

Detailed analyses of the exclusive elastic vector meson production were also presented. The energy dependence of the production cross section for the J/Ψ can be measured up to energies of 2000 GeV. Differences in models which include saturation and the simple exchange of single Pomerons can be pinned down with the help of the LHeC in this kinematic range. Copious production of heavier states, like Upsilon, is also possible. By the additional measurement of the momentum transfer, one can get access to the impact parameter dependence of the interaction.

First detailed studies on nuclear diffraction were also presented. Diffractive events in the case of nuclear targets can be coherent (with the nucleus intact) and incoherent (where the nucleus breaks down into nucleons). Theoretical predictions for both of these cases were shown. The distinction between these two scenarios poses challenging experimental problems.

Analyses devoted to the extraction of the nuclear parton distribution functions were also performed. Currently, the nuclear parton distribution functions are very poorly constrained, in particular, the gluon and sea distributions for values of $x < 0.01$ are practically unknown. LHeC measurements of DIS off nuclei could help explore this unknown regime and constrain the parton distribution functions with greater precision. Therefore, the amount of nuclear shadowing could be measured directly.

The analyses of forward jets and the impact of multiple interactions in this process, in the context of both the LHC and LHeC, were presented by Krzysztof Kutak. Multiple interactions are usually studied in the context of hadron-hadron collisions but one can also analyse these issues in deep inelastic scattering. In this case, there is the unique possibility to investigate the contribution of multiple interactions as a function of Q and x. Using the DIS process, one could more clearly disentangle multiple interactions, rescatterings and the effects of k_T (dis)ordering. Analyses of forward jets in the case of the LHeC were shown. In the case of HERA it is known that there are problems with describing this process using the standard DGLAP approach. It is important to estimate the rate and impact of multiple interactions on the forward jets cross section. Monte Carlo analyses show a substantial effect of multiple interactions in the lowest p_T bin.

A detailed analysis of the constraints of the parton distribution functions by the LHeC were shown by Juan Rojo. The analysis was done using the NNPDF approach which allows for a wide range of parton distribution parameterisations. A modest error reduction on the gluon at small-x was found, suggesting that apart from F_2, another observable is necessary to further constrain the parameterisation. Indeed, when the fit was supplemented by the simulated data on the longitudinal structure function, there was a sizable error reduction in the determination of the gluon density. Valence distributions were not well constrained by the additional LHeC data. Given the fact that the experimental measurement of the longitudinal structure function poses various challenges and can be very difficult at the LHeC, a natural question which arises is whether one can use another observable to decrease the error on the extraction. Indeed, the measurement of the charmed structure function at low Q and low x provides a very tight constraint on the gluon distribution function at low x. Another important observation from these analyses was that the strange quark distribution can be constrained by exclusive charm production $sW \to c$.

The prospects for the measurement of the light Higgs boson at the LHeC were presented by

Uta Klein. The measurement of the Higgs production at the LHeC can be complementary to the discovery at the LHC. If a Higgs with mass < 200GeV is discovered at the LHC, Higgs boson couplings and the total width may be extracted after several years of running. However, even then a measurement of the bottom Yukawa coupling will be extremely challenging since the $H \to b\bar{b}$ dominant at $m_H \leq 130$ GeV is overwhelmed by QCD backgrounds for b-jets. An electron-proton collider can add valuable information with respect to the LHC measurements, in particular if a light SM Higgs was discovered and some knowledge of the total width and some boson couplings are known. Detailed analyses of Higgs production were presented, including evaluations of the cross section, rates and the effects of the detector acceptance. The importance of efficient b-tagging was demonstrated in helping reduce the background. A promising study of the use of forward jet tagging to improve the purity of the Higgs boson signal in the $H \to b\bar{b}$ decay mode was also shown. In this case forward jet tagging in charged current events strongly enhances the signal-to-background ratio. There is also a need to study neutral current Higgs searches which constitute an important benchmark process for understanding the Higgs to ZZ coupling.

Georges Azuelos discussed Beyond Standard Model physics searches which could be performed at the LHeC. An electron-proton collider like the LHeC can complement the LHC in understanding new physics phenomena. It also offers more precision and a more complete interpretation of the LHC discoveries. There are many examples of new physics that can be explored at the LHeC. These include leptoquarks, contact interactions, excited fermions, compositeness, heavy leptons, supersymmetry and much more. Cross sections for leptoquark production are generally larger at the LHeC than at the LHC. If leptoquarks are discovered, the LHeC can determine their quantum numbers and couplings. For example, fermion number can be obtained from the asymmetry $A = \frac{\sigma_{e^-} - \sigma_{e^+}}{\sigma_{e^-} + \sigma_{e^+}}$ in single leptoquark production. The charge of the leptoquark can also be determined. The asymmetry which can be measured at the LHC has much lower precision. Detailed analyses were also performed on the estimates of the LHeC capabilities in searches for excited leptons in the $e - \gamma$ mode. Cross sections and the sensitivities to masses and couplings for different LHeC configurations were evaluated. The LHeC was demonstrated to have much better sensitivity compared with the LHC in these searches. Analyses of LHeC searches for contact interactions, heavy leptons and diquarks were also presented.

3. EIC

There were nine talks related to the design and physics possibilities of the EIC. The Electron Ion Collider is the proposed facility for the collisions of electrons with nuclei (and also protons) with a location in the United States. Currently two proposals are under investigation, one at Brookhaven National Laboratory, the eRHIC machine, and the second one in Jefferson National Laboratory, the ELIC machine. A unique feature of the EIC, apart from DIS on nuclei, would be the possibility of having polarised target beams allowing the measurement of the spin structure of nucleons.

Abhay Deshpande presented an introduction and overview of the EIC project. Among the major scientific goals driving the EIC are the nucleon spin structure and nuclear structure. Having polarised beams at high luminosity, EIC would be a valuable high-energy electron-proton collider able to measure the details of the nucleon spin structure in an extended kinematic range. In particular one could extract the polarised quark and gluon distributions. A wide range of kinematics is crucial to access the longitudinal spin structure (low x is critical) and transverse spin structure (where a wide range in Q^2 is important). Important correlations between partons in the proton could be unraveled by measurements of the exclusive processes, and by subsequent extraction of the generalised parton distribution functions. Thanks to its very high luminosity, the EIC would be capable of precision measurements of the QCD and Electroweak parameters in the Standard Model.

In addition to the polarised structure, the EIC would also be able to measure the standard unpolarised nucleon structure and extract the unpolarised quark and gluon distributions with great precision. Having nuclear targets, the EIC would be the first electron-ion collider in the world. Nuclear structure, the role of partons in nuclei and confinement in nuclei will be analysed through the comparison of electron-proton and electron-ion scattering. Details and differences of the hadronisation mechanisms in nucleons and in nuclei can be effectively studied using this collider. In particular, the effects of the nuclear medium on parton evolution can be investigated. The EIC would be able to utilise different nuclear targets thus making it possible to analyse in detail the A dependence of the different observables.

Ilan Ben-Zvi discussed details of the design of the eRHIC machine. eRHIC would be an accelerator complex located at BNL, which will utilise the existing RHIC accelerator for protons and nuclei and collide them with electrons. The basic energy parameters for eRHIC would see leptons accelerated to energies between $4-30$ GeV. RHIC could accelerate protons (with polarisation) to energies in the range $50-325$ GeV and light (d,Si,Cu) and heavy ions (Au,U) to energies of $50-130$ GeV/u. In addition, one could have polarised light ions He^3 with energies up to 215 GeV/u. In general this provides a range in centre-of-mass energies between 15 and 200 GeV. The process of the design and building of the machine includes staging, with stage 1 consisting of building first a medium energy eRHIC: MeRHIC with an initial luminosity of $10^{32}-10^{33}$ cm^{-2}s^{-1} and 4 GeV electrons. In this stage a 3 pass 4 GeV energy recovery linac would be built with a single interaction point and the MeRHIC detector. The second stage would be the high energy stage of eRHIC. This would be achieved by adding additional linacs as well as recirculating passes in the RHIC tunnel. In this stage the projected nominal luminosity is $10^{33}-10^{34}$ cm^{-2}s^{-1}. Another design approach is also presently under consideration: which foresees staging everything in the eRHIC tunnel. In this case the energy of the electron beam will increase from 5 GeV to 30 GeV by building-up the linacs. This latter approach has the advantage of being the most cost effective design.

Yuhong Zhang described the proposal and design status for a high luminosity polarised medium energy electron-ion collider at JLab: ELIC. The primary goal for this machine would be to have a very high luminosity, up to 10^{35} cm^{-2}s^{-1}, and a very high polarisation for both electrons and ions. The ELIC design combines the existing high repetition, high polarisation electron beam from CEBAF with a new ion complex and new collider rings. The design of the ion accelerator complex assumes building the sources, linac and then the accelerator ring with a figure 8 design with a size of around 630 m. This shape helps to preserve the full polarisation of ions. There are actually three rings envisaged, electron, warm-proton and cold-proton, at the first stage of the project. In this stage, a medium energy range would be achieved with protons being accelerated up to 60 GeV. In the second stage a larger ring of size 1800 m will be built (two rings, one for electrons and one for ions), and the ions would be accelerated up to 250 GeV.

The design goals which will lead to high nominal luminosity include: high bunch collision frequency (0.5 GHz, can be up to 1.5 GHz) , very small bunch charge ($< 3 \times 10^{10}$ particles per bunch), very small beam spot size at the interaction points ($\beta_y^* \sim 5mm$) and short ion bunches ($\sigma_z \sim 5mm$).

Matthew Lamont discussed the proposal for the detector at the electron - ion collider eRHIC. Due to the wide scope of the EIC physics program, there are many requirements for the detector design at eRHIC. The same detector needs to be used for the inclusive, semi-inclusive and exclusive reactions in the case of electron-proton collisions. In this case one needs to have a large acceptance for both medium and forward rapidity. Particle identification is crucial, this includes e, π, K, p, n over a wide range of scattering angles and momentum. To be able to identify processes with charm an excellent secondary vertex resolution is required. The detector should also have a small systematic uncertainty for e/p polarisation and luminosity measurements. There are also additional challenges stemming from the ion physics programme, such as the need for tagging of the struck nucleus in exclusive and diffractive reactions. Also since the design of the machine will be staged, with different energy ranges, it is important to have the same detector suitable for all energies. A first design of the MeRHIC detector has been presented with the simulations of the particle interactions in GEANT3.

There have also been interesting investigations concerning the (re)usage of the current RHIC detectors (STAR and PHENIX) for the eRHIC machine. Studies of the usage of the STAR detector in electron-ion collisions look very promising at this moment, as the geometry and acceptance of the detector are suitable for DIS. PHENIX cannot be used for eRHIC in the present configuration as the acceptance is not matched to DIS kinematics and the detector would require significant modifications and upgrading. There is currently a proposal under study of an upgraded version of PHENIX, with a new central detector and the replacement of the south muon arm with an end-cap spectrometer.

Various aspects of physics with nuclei at the EIC were discussed by Will Brooks. Physics questions that could be addressed by the EIC collider at lower energies include the problem of the lifetime of an energetic free quark and the formation time of a hadron which starts from an energetic light quark. At higher energies, one can test the breakdown of QCD factorisation and address the issues of the increase in jet broadening and quark energy loss. The EIC can address the questions of the impact of cold nuclear matter on the production and formation mechanisms of hadrons. In vacuum, the propagating quark emits QCD radiation and subsequently enters the phase of hadronisation. The characteristic times of these two phases are the production time and the formation time of the hadron. If both phases are affected by the presence of the nuclear medium then one can estimate this effect by measuring the p_T broadening (which gives access to the rescattering of the propagating quark in the medium), and by looking into the hadron attenuation, which gives access to the impact of the nuclear medium on the formation of the hadron. The EIC offers the unique possibility to pin down the value of the saturation scale, additionally as a function of the A number. The saturation scale is a dynamical scale characterising the onset of the dense partonic regime. It was shown, within the dipole model, that the saturation scale can be evaluated by the measurement of the transverse momentum broadening of the hadrons in SIDIS. This puts further requirements on the experiment. In particular, one needs very good transverse momentum resolution. One also needs a very good particle identification and an ability to measure two-jet events.

Cyrille Marquet gave a presentation on a relation between the k_T factorisation approach at small x and the transverse momentum distribution factorisation in the process of semi-inclusive DIS. The semi-inclusive DIS (SIDIS) process in the dipole picture was discussed with the equivalent k_T factorisation in the momentum representation. This representation is suitable for the description of DIS at small-x. The k_T factorisation makes use of the unintegrated gluon distribution function, which can include the saturation through nonlinear effects in the evolution. The TMD factorisation was derived up to the leading power of $1/Q$. In order to make the comparison between the two formalisms, the large Q limit was taken in the k_T result and the small x limit was taken in the TMD factorisation approach. The two formalisms are then equivalent provided one makes suitable identification between the quark transverse momentum distribution and the unintegrated parton distribution function from the small x result. Saturation effects can still be included in this definition from a suitable choice of the unintegrated parton distribution function. A first comparison with the H1 data was performed with good results, the data show the same trend as the calculation. At the EIC, the SIDIS measurement provides direct access to the transverse momentum distribution of partons in the proton and/or nucleus, and the saturation regime can easily be investigated. Dijet production was also discussed and the problem of TMD factorisation breaking in this case. Breaking of TMD factorisation in dijet production means that one cannot use information extracted from one process to predict the other. An alternative approach was suggested based on the experience with the k_T factorisation where an improved definition of the parton distribution functions (in terms of classical fields) is possible. In this way by expanding the small x dijet cross section at large Q one should be able to identify the universal TMD parton distribution function.

A set of measurements whose QCD description requires the use of TMD pdfs are Transverse Single Spin Asymmetries (TSSAs). This was discussed by Leonard Gamberg. He focused on the time-reversal odd (T-odd) distributions, first introduced in the context of polarised $p+p$ collisions. When considering SIDIS in the TMD-factorisation framework, the T-odd structure is due to the gauge link intrinsic to the TMD pdf definitions in order to ensure gauge invariance. The link describes initial/final-state interactions of the active parton due to soft gluon exchanges with the target remnant. Though these interactions are non-perturbative, many studies have been performed to model the T-odd TMD pdfs approximating the soft gluon rescattering effects by the perturbative one-gluon exchange. Considering the Boer-Mulders function - one of the TMDs that enters the formulation of TSSAs - Leonard presented a model in which higher-order contributions to the final-state interactions are included by applying non-perturbative eikonal methods.

Alexey Prokudin discussed the prospects of measuring transverse spin physics with the EIC machine. A new EIC accelerator with polarised beams presents a unique opportunity to unravel the three dimensional picture of the proton. As mentioned by Jianwei Qiu during the Duke workshop in March 2010: 'Usage of high energy unpolarised beams at experimental facilities, such as the LHC, undoubtedly has its advantages, but the mass of the proton can be neglected with respect to the energy of the beam. On the contrary if we have polarised beams, then the spin of the proton can never be neglected with respect to the energy. This opens a unique opportunity to study 3 dimensional spin structure of the proton.' In particular, the EIC will allow us to study how partons are distributed inside of the nucleon both in impact parameter (Generalised Parton Distributions) and momentum (Transverse Momentum Dependent distributions) space. Extraction of the Sivers

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function from the COMPASS and HERMES data allowed us to map the distribution of the u,d and sea quarks in the proton. More information on the sea quarks can be provided by the EIC. The advantage of the EIC will be the high Q range which will allow the study of twist-2 functions and higher twist content of the nucleon. Also, the range of p_T at the EIC will allow to study the intermediate region where both TMD and collinear factorisations are applicable. Studying a range of Q values at fixed x will provide information on the Q behavior of asymmetries and Q evolution of TMDs. Measuring in a range of p_T will allow for measurements of weighted asymmetries at the EIC, so that moments of TMDs could be extracted from the data. The full flavour and spin decomposition of TMDs can be attempted at the EIC.

Exclusive electroproduction of mesons and possibilities of proton imaging with the EIC was discussed by Tanja Horn. Exclusive reactions with the production of vector mesons or pseudoscalar mesons provide a valuable tool to extract the transverse momentum distributions of the target. The latter provide information which allows the transverse imaging of the nucleon. Correlations of the wave function can also be tested using this method. Transverse spatial distributions of the gluons were performed from exclusive J/Ψ and ϕ production. The transverse distribution in impact parameter space can be directly obtained by making the Fourier transform of the t dependence. The unique capabilities of the EIC will give wide kinematic coverage at high luminosity, in particular for meson production for $Q^2 > 10GeV^2$. The precise measurements will require recoil detection of the nucleon/nucleus for exclusivity and detailed t - measurements. High luminosity 10^{34} cm$^{-2}s^{-1}$ is needed to analyse electroproduction and have good statistics at high momenta transfer. By analysing the DVCS process which gives information on the singlet quark distribution one can test whether this distribution has the same size as the one coming from gluons. Analyses of the exclusive reaction with pseudoscalar mesons in the final state were performed, showing that these provide information on the spatial distribution of the non-perturbative sea. Transverse imaging with strange quarks was also performed by estimating the rates of the exclusive production of K mesons. This requires very high luminosity, beyond 10^{34} $cm^{-2}s^{-1}$. Apart from transverse imaging one can also look at the longitudinal correlations by analysing and extracting GPD's at different values of $x \neq x'$. Orbital motion of quarks and gluons can also be addressed with the EIC.

Krishna Kumar discussed the prospects of the electroweak physics programme at the EIC. With the EIC one can study with great precision flavour conserving weak interactions and hence check for signals of indirect effects of new TeV-scale dynamics manifesting itself through new neutral current interactions. Parity Violating deep inelastic scattering (PVDIS) can also be studied at the EIC. Incremental improvements can be made on DIS electroweak couplings over the 12 GeV JLab program at higher Q. Very precise weak mixing angle measurements will likely require an integrated luminosity of 100 fb^{-1}. Charged lepton flavour violation was another process that could be looked at with great precision using the EIC. Potentially enhanced lepton flavour violation is within the reach of the EIC. By investigating this mechanism it could be possible to decipher the mechanism of neutrinoless double beta decay search for R-parity violating supersymmetry.

4. Proposed measurements at COMPASS

4.1 DVCS measurement at COMPASS

Eva-Maria Kabuss discussed in details the prospects of the measurement of deeply virtual

Compton scattering at COMPASS. COMPASS utilises CERN's high energy muon beam: $100-160$ GeV with 80% polarisation. COMPASS offers access to a unique kinematic range between HERA and the HERMES/JLab experiments. The intermediate range in x provides access to information on the sea and valence quarks. The high x limit comes from acceptance, and Q^2 is limited to 8 GeV^2 from the cross section and the range of the luminosity $10^{32} cm^{-2} s^{-1}$. The planned measurements include deeply virtual Compton scattering and deeply virtual meson production.

Simulated data on DVCS were shown, in particular the projected precision of the extraction of the slope of the momentum transfer after 2 year's of data taking with an integrated luminosity of $L = 1222$ pb^{-1}. The range in x extends from 10^{-1} to 10^{-2} thus complementing previous measurements at HERA and together with the HERA data will allow the x or energy dependence of the extracted slope to be tested. This measurement provides many challenges to the experimental setup. Currently the project is going to be split into two phases. In the first phase the study of GPD's with a proton target is planned. The liquid hydrogen target which is surrounded by the recoil detector is currently under design. There is also a need for an upgrade of the electromagnetic calorimetry. In the second phase the study of GPD's with a transversely polarised NH_3 target is envisaged. This will require a transversely polarised target with a recoil detector and there are two different options discussed at this stage. These two different phases will constrain two different types of GPD functions.

4.2 Drell-Yan measurement at COMPASS

A future COMPASS Drell-Yan experiment was presented by Oleg Denisov. The objective of this measurement is to check the universality of the Sivers and Boer-Mulders function and compare it with the SIDIS case. Theoretical motivation for the measurement stems from the basis of the factorisation approach in which the parton distribution functions enter as gauge invariant objects. To ensure gauge invariance, Wilson lines are introduced. In principle the Wilson line direction is process dependent. The direction of the Wilson line is different in the SIDIS and Drell-Yan processes which results in the opposite sign of the Sivers functions in both cases. This is a very fundamental feature of QCD and stems from the T-symmetry property. Thus the direct measurement of the Sivers functions in SIDIS and in Drell-Yan can test this theoretical statement. The setup of the COMPASS experiment to measure the Drell-Yan process includes using the π to measure the process $\pi^- p \to \mu^+\mu^- X$. In the kinematic range accessible at COMPASS, the contribution from valence quarks is dominant. The fusion of the $u\bar{u}$ pairs prevails. In addition the average transverse momentum is estimated to be about $\langle p_T \rangle \sim 1$GeV. In this case the effects induced by TMDs are expected to be dominant with respect to the higher QCD corrections. The process has a small cross section and therefore requires high luminosity delivered to the experiment. In addition the polarised target is the key instrument of the program. It was demonstrated that with a beam intensity of $I = 6 \times 10^7$ particles/second a luminosity of $1.7 \times 10^{33} cm^{-2} s^{-1}$ can be achieved. Therefore in two years of data-taking one can expect to be able to collect more than 200000 Drell-Yan events in the mass range of $4 < M_{\mu\mu} < 9$ GeV. A series of beam tests were performed and the feasibility of this measurement was proven. The statistical error on single spin asymmetries is at the level $1-2\%$ after two years of data taking.

5. Polarised Drell-Yan measurement at J-PARC and RHIC

Yuji Goto discussed ideas for the measurement of the polarised Drell-Yan process at J-PARC and at RHIC. The J-PARC proposal envisages the measurement of dimuon production at the 50 GeV proton synchrotron. The experimental difficulty is to develop the facility to be able to produce and maintain the polarisation. The proposed scheme for the polarised proton acceleration at J-PARC is based on the successful experience of accelerating polarised protons to 25 GeV at BNL AGS. It was demonstrated by detailed calculations that pQCD corrections can be controlled at the J-PARC energy. Sensitivity to dimuon masses of the order $2-6$ GeV is possible with this setup. This measurement would probe the values of longitudinal momenta of about $x_1 = 0.05-0.1$ and $x_2 = 0.001-0.002$.

Polarised Drell-Yan measurements can be also performed at RHIC. The advantage of RHIC is the availability of the polarised proton beams. The experiment can also reach high centre-of-mass energies: $\sqrt{s} = 500$ GeV. Initial simulations with PYTHIA were performed for the PHENIX muon arms. Assuming the angle and energy cuts only, and the RHIC II luminosity of $1,000\ \mathrm{pb}^{-1}$, simulations were performed giving a yield of about 110K events above the energy cut of 2 GeV. The dimuon mass range was $4.5-8$ GeV. Another option considered is a fixed target experiment at RHIC. A simulation with PYTHIA for that case was also performed. This experiment has a sensitivity to larger values of the longitudinal momentum fractions in the incoming partons, typically $x_1 = 0.24-0.4$ and $x_2 = 0.1-0.2$. For the fixed target experiment to be competitive with the collider setup an appropriate target thickness is required. Additional requirements for the experiment are being put forward like the size of the experimental site and possible target position (with proper beam operation) and the radiation issues (beam loss and dump requirements in this case).

6. Fermilab E-906/Seaquest experiment

The prospects for the measurement of flavour asymmetry of the light quark sea at Fermilab was presented by Paul Reimer. The precise measurement of the asymmetry is vital for the extraction of parton distribution functions. A naive expectation was that the sea is symmetric, that is that $\bar{u} = \bar{d}$. The first indication that this expectation is not valid came from the NMC measurement of the Gottfried sum rule. Further experiments, the Drell-Yan measurements at NA51, confirmed the fact that $\bar{d} > \bar{u}$ at $x = 0.18$. A very successful measurement was performed by the Fermilab experiment E-866/NuSea where the Drell-Yan processe was measured and the $\bar{d}/\bar{u}$ ratio was extracted for the range of x, $0.015 \leq x \leq 0.35$. The main goal of the planned experiment E-906 is to measure this ratio with increased precision and over slightly larger values of x. The experiment will utilise the proton beam from the main injector at Fermilab, with 120 GeV energy. The target will include $^1H,^2H$ and nuclear targets as well, with data taking in $2010-2013$. This experiment will have a larger cross section and larger luminosity with reduced backgrounds as compared to E-866. E-906/SeaQuest will extend the measurements of E-866 and reduce the statistical uncertainty. E-906 expects the systematic uncertainty to remain at approximately 1% in the cross section ratio. The projected range in x of the measurement spans $0.1-0.45$. By using the nuclear targets one will be able to study whether the nuclear effects are the same for the sea and valence distributions. The effects of nuclear binding will be analysed from the extracted sea parton distributions.

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7. Neutrino experiment MINERvA

The status of the neutrino experiment MINERvA at Fermilab was presented by Heidi Schellman. The main goal of this experiment is to gain a basic understanding of the neutrino interactions in the energy range of $1-10$ GeV. This provides an important input for the neutrino oscillation experiments as well as allowing a detailed study of the transition regime between perturbative and non-perturbative physics. The MINERvA experiment utilises the NuMI beam at Fermilab, the detector itself is situated in front of MINOS. The MINERvA detector has a finely segmented, fully active scintillator tracking region surrounded by hadronic and electromagnetic calorimetry. The MINERvA experiment can utilise a wide range of nuclear targets which include: He, C, Fe, Pb, H_2O, CH. Substantial progress in the analysis of the first data was shown. Sample events from rock muons (created by upstream neutrino interactions) which constitute a valuable absolute energy calibration tool were shown. Quasi elastic events and elastic event candidates were also successfully identified. Muon kinematics in the quasi-elastic events were determined from angle, range and momentum in MINOS. Proton kinematics were reconstructed from angle and range. Analyses with π^0, identified as an EM shower in the electromagnetic calorimeter were also shown. A four-month run in $\bar{\nu}_\mu$ mode with 60% of the detector was completed. The reconstruction of these data has been started and the installation of the full detector was completed in March 2010. Currently the data are being taken with a ν_μ beam with the full detector. In the future, by using different targets, MINERvA will be able to measure the A dependence of the inclusive structure functions and, possibly, test nuclear shadowing mechanisms by looking at differences in the final state.

8. The HERMES recoil detector

Alberto Martinez de la Ossa described the commissioning status and analyses prospects for the HERMES recoil detector. The exclusive processes like DVCS or exclusive meson production were measured by HERMES without the detection of the recoiling proton. The recoil detector measures the recoiling proton, thus greatly improving the measurement by ensuring the exclusivity of the event sample. Pions and photons can also be detected. This setup leads to a substantial reduction of the background which in this case is below 1%. The recoil detector consists of a superconducting solenoid (with 1T field), a photon detector, a fibre detector which is used for the track reconstruction and a silicon strip detector used for track reconstruction of low momentum protons. The recoil detector offers a large azimuthal acceptance (76%) with a minimum reconstructible proton momentum of 90 MeV. The analysis of DVCS data with the recoil detector consists of using first the forward spectrometer to select $e-\gamma$ topologies. Next, the missing momentum and angle are calculated. Using the recoil detector, one selects the proton candidate and performs the search for DVCS correlations in angle and momentum. The exclusivity cut is then applied $|\Delta p| < 1$ GeV. The background levels are very low at $< 1\%$. Event selection refinements were also performed by refitting the tracks in the recoil detector using a global kinematic hypothesis of DVCS. The validity of the hypothesis is then checked in terms of the χ^2 of the fit. The DVCS proton candidate was then selected as the candidate with the smallest χ^2. Monte Carlo simulations show an excellent expected performance for DVCS measurements. Early data behaves as expected and systematic studies are now in progress. The same technique as that used in DVCS was used to analyse the exclusive meson production. Using a deuterium target, it is also possible to measure the 'tagged' neutron structure function. This is done by measuring the effective structure function of the neutron by means of 'tagging' spectator protons of electron DIS off deuterium.

9. PHENIX calorimetry and trigger upgrades

Anselm Vossen presented the upgrades of the forward parts of the PHENIX detector. This includes the forward electromagnetic calorimeter and the forward muon trigger upgrade. The measurement of forward π^0, γ and correlations are important for exploring the behaviour of the gluon at small x. The measurement of the forward direction in dA collisions tests the small x part of the wave function of the dense nucleus. Knowledge of the initial state is important for the quantitative interpretation of experimental results in heavy ion collisions. Due to the limited space of the forward PHENIX region the calorimeter needs to have a high density. The chosen technology is that of a Silicon-Tungsten sampling calorimeter. Initial detector studies were performed. Good angular resolution, which is critical for jet measurements, was demonstrated and detailed detector performance studies exceed minimum requirements. A second proposal for modifications to the PHENIX detector is the forward muon trigger upgrade. This upgrade is necessary to perform the measurement of W production in the collisions of polarised beams at $\sqrt{s} = 500$ GeV. By using the polarised beams one can measure forward asymmetries in this process. They provide essential information about sea quark polarisations. Using the leptonic decays of the W there is no uncertainty coming from fragmentation. The PHENIX upgrade will enable measurements in a unique kinematic region. Both the hardware and software are now in place for polarised proton-proton collisions at $\sqrt{s} = 500$ GeV in run11.

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