Prospects of DIS with fixed targets

Ewa Rondio

A. Soltan Institute for Nuclear Studies
00-681 Warsaw, Poland, Hoza 69
ewar@fuw.edu.pl

Abstract. Some prospects for important measurements in Deep Inelastic Scattering on the fixed targets are discussed. The subjects selected are parity violating asymmetries and deeply virtual Compton scattering. The last subject is related to the determination of generalized parton distribution. Possibilities for such measurements in the Compass experiment at CERN with high intensity proton beam are presented.

Keywords: DIS, parity violating asymmetries, deeply virtual Compton scattering
PACS: 13.88.+e, 13.60.Le

INTRODUCTION

There is no need to explain how important was the lepton hadron scattering for studies of nucleon structure. Some subjects in this field are still waiting for more precise or additional data. Presently the scene of such experiment is shrinking drastically. Some of the effort is going into collider experiments which can extend kinematic coverage, but some places are simply closed. Presently on the map we have CERN with Compass experiment, DESY with Hermes and in the US: Fermilab, SLAC and Jefferson Laboratory. The present and future plans of Jefferson Laboratory will be discussed in more details in separate presentation.

For a long time the main goal for DIS experiments was determination of the nucleon structure and in particular parton distribution functions. This was the main subject for first generation experiments and now the precision is given by extended range provided by collider measurements (HERA). For spin dependent distributions the fixed target data are still the only one and plans for step toward collider were presented at this conference. Subject still requiring precision data is a test of assumed symmetries like $u_p = d_n$ or $s = \bar{s}$ and measurements of the behavior at high x. The new data are needed for different approach to the nucleon structure - determination of generalized parton distributions (GPD) and here place for fixed target seems to exist again, as the statistics required is very high.

PARITY VIOLATING ASYMMETRIES

After the discovery of parity violation in beta decay, Zel'dovich predicted an analogous parity violating neutral current interaction [1]. The asymmetry should manifest in the measurements of cross section for leptons with spin parallel or anti-parallel to the momentum:

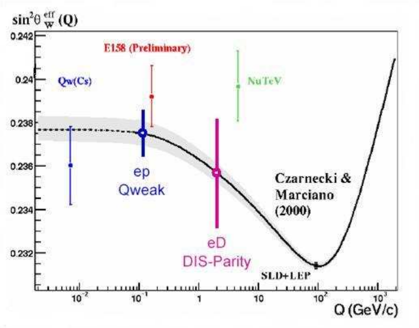

FIGURE 1. The running of $sin^2\theta_W$ in the $\bar{MS}$ scheme, showing measurement from atomic parity violation on Cs (APV Cs) [2], NuTeV result from ν DIS [3], combined measurements at Z^0 pole. Precision of proposed measurements by Q-Weak and SLAC E-158 Moller scattering as well as DIS parity violating asymmetries on deuteron target possible at SLAC or J-Lab after 12 GeV upgrade (DIS-Parity). the picture originates from [4].

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \approx \frac{|A_Z|}{|A_\gamma|} \approx \frac{GQ^2}{4\sqrt{2}\pi\alpha} \tag{1}$$

and appears due to the interference between the weak and electromagnetic amplitudes. Present experiments allow measurements of asymmetries which are at the level of parts per million expected is such processes. The measurements of such asymmetries will allow verification of important questions. Within the Standard Model, the asymmetry is sensitive to the parameter $sin^2\theta_W$. Extensions of the Standard Model may modify the couplings, changing the apparent value of $sin^2\theta_W$ extracted from asymmetry measurement. An electron axial-vector coupling and vector coupling of target particle allow probing of nucleon structure. In the case when vector coupling of the target is very well known, or the ratio of vector to electromagnetic amplitude does not depend on the hadron structure such measurement is probing new physics.

Example of a problem still waiting for explanation is the so called NuTeV anomaly. In fig.1 presents measurements of $sin^2\theta_W$ at different scales (Q^2), where the measurement done with neutrino and anti neutrino beams shows significant deviation from the expectations [6]. Experimentally the precision is very well controlled and seems to be no reason to doubt the result. The only possible explanation is that one of the assumptions made to derive $sin^2\theta_W$ from the cross section ratio is not fulfilled. These assumptions are: isospin invariance (u quark in the proton is as d quark in the neutron), sea momentum symmetry for c and s quarks and nucleon effects common for W and Z boson exchange. The measurements of A_{PV} in DIS scattering at high x done on isoscalar and proton targets can bring enough information to verify the isospin invariance.

Additionally such measurements will constrain parton distribution function at high x and nucleon wave functions. Behavior of ratio u/d quarks for $x \to 1$ is predicted quite differently by SU(6) symmetric, SU(6) breaking models and by QCD [5]. A lot of such measurements are planed at Jefferson Laboratory with presently available beams and after 12 GeV upgrade. Measurements at higher energies could be done at SLAC, but there are no plans for such activity.

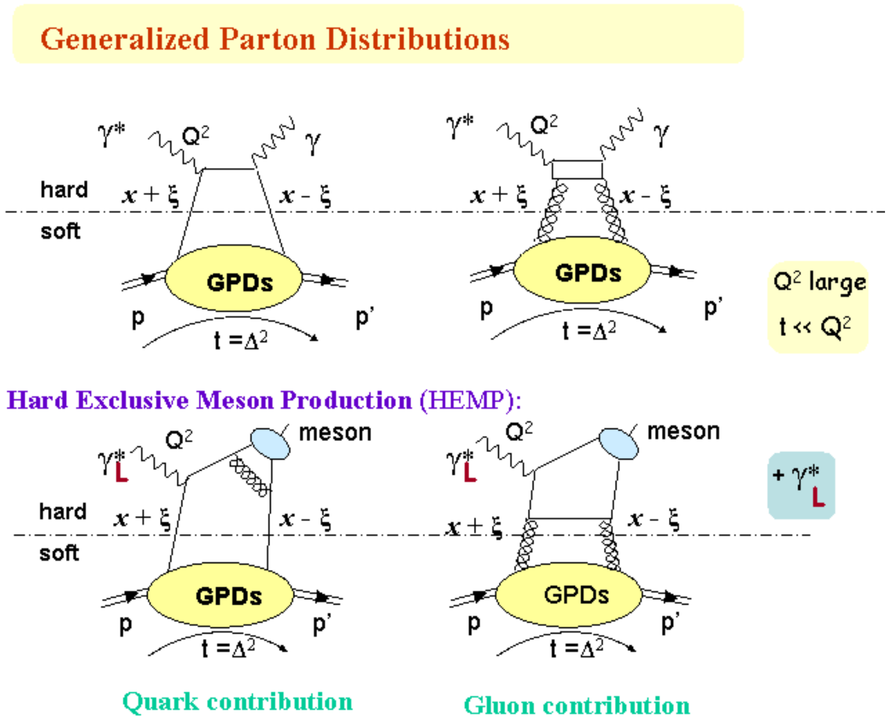

FIGURE 2. Handbag diagrams for the Compton scattering amplitudes (upper diagrams) and meson production amplitudes (lower diagrams). Diagrams with quark contributions are shown on the left and with gluons on the right.

THREE DIMENSIONAL PICTURE OF THE PARTONIC NUCLEON STRUCTURE

The interpretation of inclusive deep inelastic scattering results in terms of parton distributions allow precise description of the nucleon structure in terms of parton distribution functions (PDF). The PDF give one dimensional picture in which we know partons momenta. More precise information can be obtained from exclusive reactions, from which one can obtained three dimensional picture. The qualitatively new information from measurements of exclusive processes and their dependence on the momentum transfer can be translated to the information on distributions perpendicular to the direction of motion, giving three dimensional picture of the nucleon. In such approach Generalized Parton Distributions [9] are introduced.

There are different possibility to get information about such objects. One of them, which at present looks most promising, is Deeply Virtual Compton Scattering (DVCS). The connection between DIS and DVCS comes from optical theorem.

The process would be virtual photon scattering on the nucleon with real photon and nucleon in the final state. The inclusive meson production can be related to GPD's by the quark-parton duality. The handbag diagrams for these processes are presented schematically in fig.2

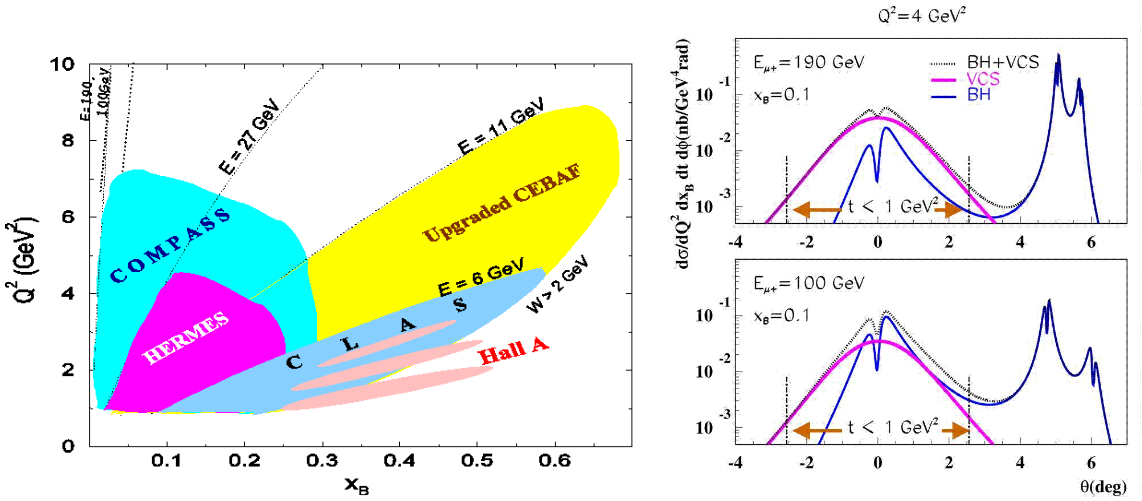

FIGURE 3. Presentation of the DVCS measurements: left figure - kinematic regions covered by present and planned experiments, right - for Compass experiment the expected contributions from Bethe-Heitler process and from genuine DVCS process, which produce identical final states. Upper figure is for incoming muon energy of 100 GeV and lower for 200 GeV.

Several theoretical publications [7],[8],[10] have shown that DVCS scattering can be factorized into hard-scattering part and non-perturbative nucleon part. The factorization is valid when Δ (see fig.2) is small compared to Q^2. In the diagrams shown in fig.2 the lower blobs represent the soft structure of the nucleon in terms of GPD's, conserving quark helicity): $H, \tilde{H}, E$ and $\tilde{E}$. Second moments of PDG's (with momentum transfer going to zero) allow the determination of angular momentum (spin+orbital) carried by quarks from the Ji sum rule [7]

$$2J_q = \int x|H+E|(x,\xi,0)dx \tag{2}$$

Several experiments are measuring DVCS processes presently, first results were already published from Hera, Hermess and J-Lab [11]. The complementarity of these results and the measurement planned in the Compass experiment at CERN is shown in fig.3.

The Compass spectrometer has to be equipped with recoil detector. Assuming 6 month of data taking with presently available muon intensity and with 2.5m liquid hydrogen target, the Q^2 is limited by 7.5 GeV^2. The increase of luminosity by factor two will increase the Q^2 coverage up to 11 GeV^2 and by factor 4 to 17 GeV^2. Such increase can be possible if the proton intensity upgrade plans at the CERN accelerator complex become reality. The upgrade will require modifications of injection to the PS, design and construction of new linac and possibly superconducting proton linac (SPL). The detailed discussion about this solution can be found in [13].

The measurement of DVCS with high energy muon beam gives a possibility to control the relative contributions of this process and Bethe-Heitler scattering. For energy about 200 GeV the DVCS cross section is dominant, while at 100 GeV both processes contribute with compatible strength and the interference term will provide DVCS amplitude. This allows access to real and imaginary parts of the amplitudes. From the sum and difference of the cross sections measured with positive and negative muon beams the DVCS and BH contributions can be separated. For more details and estimation of the sensitivity for such measurement see [12].

SUMMARY

In summary we can say that there are interesting measurements waiting for the fixed target experiments of DIS type. Some of the most interesting possibilities were presented in this talk. One of them, the detailed studies of the parity violating effects, gives possibility of unique tests of the standard model and searches for physics at the TeV scale. Measurements of this type will be performed at Jefferson Laboratory, but data at higher beam energies will also be extremely useful. The other measurements discussed here, determination of Generalized Parton Distributions in DVCS processes, can give access to three dimensional picture of the nucleon interior. For this kind of studies wide kinematic coverage is very important. Presently realized measurements at DESY and JLab can be complemented by future measurements in Compass experiment at CERN.

ACKNOWLEDGMENTS

The author would like to thank N.d'Hose for help in preparation of the part of this talk related to DVCS studies and K.Kurek for very useful discussions. It is a pleasure to thank the organizers for the stimulating meeting and providing very good opportunity for useful discussions. This work was supported by KPN grant 621/E-78/SPB/CERN/P-03/DWM576/2003-2006.

REFERENCES

1. Ya. B. Zel'dovich, *J. Exptl. Theoret. Phys. (USSR)*, **36**, 1959, 964.
2. S. C. Bennett and C. E. Wieman, *Phys. Rev. Lett.*, **82**, 1999, 2484.
3. G. P. Zeller *et al.,* Phys. Rev. Lett.*, **88**, 2002, 091802.*
4. *P. E. Reimer, CP721, Neutrino Factories and Superbeams:*
5. *K. S. Kumar, CP675, Spin 2002: 15'th Spin Physics Symposium on Polarized Electron Sources and Polarimenters, AIP 2003, 142.*
6. *J. T. Londergan, contribution to 2nd workshop Structure of Nucleon at high Bjorken x, France, AIP Conf.Proc.747, 2005, 205.*
7. *X. Ji,* Phys. Rev. Lett. ***78**, 1997, 610;*Phys. Rev. ***D55**, 1997, 7114.*
8. *A. V. Radyushkin,*Phys. Rev. ***D56**, 1997, 5524.*
9. *M. Diehl, DESY-thesis-2003-018, hep-ph/0307382 and ref. therein.*
10. *J. C. Collins, L. Frankfurt, M. Strikmann* Phys. Rev. ***D56**, 1997, 2982.*
11. *H1, C. Adloff et al.,* Phys. Lett.*, **B517**, 2001, 47; ZEUS, S. Chekanov et al.,* Phys. Lett.*, **B573**, 2003, 46; CLAS, S. Stepanyan et al.,* Phys. Rev. Lett.*, **87**, 2001, 182002; HERMESS, A. Airapetian et al.,* Phys. Rev. Lett.*, **87**, 2001, 182001.*
12. *N. d'Hose contribution to SPSC Villars Meeting on a Future Fixed Target Programme at CERN*
13. *contributions to the workshop: Physics with a Multi-MW Proton Source, CERN, Geneva, May 25-27,2004.*