Activity Report 2014 - JLAB12

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1 Introduction

The Frascati JLAB12 group participates into the physics program carried on by the CLAS collaboration in the Hall B of the Jefferson Laboratory (JLab). The physics program of the group is focused on the precision study of the three-dimensional structure of the nucleon and its internal dynamics. This is achieved through the determination of three-dimensional parton distribution functions: the Transverse Momentum Dependent parton distribution (TMD) and the Generalized Parton Distribution (GPD) functions. The former describe the quarks and gluons inside the nucleon in the 3D momentum space and are accessible in Semi-Inclusive Deep Inelastic Scattering (SIDIS) measurements. The latter describe longitudinal momentum distributions at a given transverse spatial point and are measured in exclusive reactions. The structure functions containing the TMDs and GPDs enter in the Fourier components of the cross section of the process and they are accessed through the measurement of single or double spin asymmetries.

The operation of the JLab electron accelerator has been shut down in May 2012 to increase the maximum beam energy up to 12 GeV, to upgrade the three existing experimental halls and to build a fourth new hall. In Hall B, the new CLAS12 spectrometer is now under construction. To improve the particle identification capabilities of this new detector also to the kaons, the Frascati group is involved in the construction of a RICH detector.

In the period covered by this report, two analysis items have been completed and published and others are still going on. For the RICH activity, the R&D has been mostly completed and the construction of the detector has been started.

2 Data analysis activity

2.1 GPD measurements

The simplest way to access GPDs is to study the Deeply Virtual Compton Scattering (DVCS) exclusive process, in which a hard photon is produced in the final state. The Fourier coefficients of the cross section can be written in terms of the so-called Compton Form Factors (CFF), particular combinations of GPDs. By measuring cross section asymmetries, it is possible to extract from the data these CFF.

Data have been collected with 5.5 GeV energy polarized electron beam and a longitudinally polarized proton target. This allowed to measure at the same time Single Beam and Target Spin Asymmetries (BSA and TSA) as well as Double Spin Asymmetries (DSA). All the three final state particles of the reaction (the scattered electron, the recoil proton and the hard photon) are clearly identified in CLAS so that the kinematics of the process can be fully reconstructed.

The analysis has been completed and approved by the CLAS Collaboration during 2014 and the results have been published in two papers with members of the LNF-JLAB12 group as first
Figure 1: The $t$-dependence for each $Q^2$-$x_B$ bin of $H_{1m}$ (black squares) and $\tilde{H}_{1m}$ (red circles). The full points are obtained by the present data (TSA, BSA and DSA), the empty points were obtained by previous data.

authors (see Publications 1 and 2). As an example of the results, we show in Fig. 1 the $t$, $Q^2$ and $x_B$ dependence of the CFF $H_{1m}$ and $\tilde{H}_{1m}$ (full circles) compared with previous extractions (empty circles). Our new data extend over a much larger kinematic region and improve the precision of previous measurements in the overlap region.

2.2 TMD measurements and extraction

The TMDs, 3D extension of the collinear Pardon Distribution Functions (PDFs), are in general measured in SIDIS experiments with a meson (pion or kaon) in the final state. In these processes, the TMDs enter in convolution integrals with the Fragmentation Functions, thus sophisticated algorithms for their extraction are required. In recent years, the calculation of the Bessel-weighted asymmetries has been proposed as a convenient extraction method, because it transform the convolution integrals in the transverse momenta into simple products in the conjugate transverse coordinate space. This approach has been tested with simulated data, using a dedicated Monte Carlo event generator in which the kinematic correlations between the parton and hadron momenta
Figure 2: The extraction of the combination $e^V$ in the WW scenario. The error bars correspond to the propagation of the experimental and DiFF errors.

have been introduced. Systematics uncertainties in the extraction of the TMDs from the data in this new approach have been evaluated for a number of reference channels. These results have been published (Publication 4).

An alternative way to the TMDs is provided by the DiHadron SIDIS processes (DiSIDIS), in which two mesons (for example two pions) are produced in the final state. In this case, the cross section takes a much simpler form, with TMDs and DiHadron Fragmentation Functions (DiFF) entering as products instead of convolution integrals. In the collinear limit, the DiSIDIS allows the access to the higher-twist PDF $e, g_T$ and $h_L$, that, together with the leading twist unpolarized $f_1$, helicity $g_1$ and transversity $h_1$, complete the collinear description of the nucleon structure up to twist-3. Measurement of DiSIDIS asymmetries with a charged pion pair has been performed with both unpolarized as well as longitudinally polarized hydrogen target as a function of the relevant kinematic variables. The analysis with unpolarized target has been completed and is now under the Collaboration review, while for the polarized target one the analysis note is in preparation.

From the Beam Spin Asymmetry (BSA) results of the unpolarized data, a preliminary extraction of the PDF $e(x)$ has been attempted. This PDF enters in the expression of the BSA together with a second term, of the same twist, containing an unknown DiFF, thus its extraction requires a theoretical assumption to model this unknown term. As an example, we show in Fig. 2 the Bjorken-x dependence of the valence quark combination

$$e^V = \frac{4}{9}e^u - \frac{1}{9}e^d$$

under the so-called Wandzura-Wilczek (WW) approximation. This analysis has been published (Publication 3).

3 Proposals of 12 GeV experiments

Two new proposals for measurements to be performed with the 12 GeV beam with CLAS12 have been presented by physicist of the LNF-JLAB12 group and approved in 2014 by the JLab Program Advisory Committee (PAC).

The first one ¹), is devoted to the study of the electroproduction of $\Lambda$ in SIDIS reaction. The goal is the extraction of the Fracture Functions, generalization of the PDFs and Fragmentation
functions that describe the production of a given hadron in the final state when the virtual photon hits a given quark in the target nucleon. These functions are accessible in the Target Fragmentation Region, where the final hadron is produced by the fragmentation of the nucleon quark remnants.

In the second one 2), the goal is the extension, with higher beam energy, larger kinematic coverage and better statistical precision, of the studies already in progress in the di-hadron SIDIS electroproduction. These new measurements will be performed using both hydrogen and deuterium target, so that the valence quark decomposition of the $e(x)$ will be possible.

4 The CLAS12 Rich for the Hall B of JLab

The new CLAS12 detector under construction for the Hall B will have unique features (luminosity, resolution and large acceptance) to allow substantial progresses in the nucleon structure studies. In its baseline configuration, CLAS12 allows the identification of particles with the combination of time-of-flight and Cherenkov detectors in six azimuthal independent sectors. While these detectors are adequate for the identification of electrons, pions and protons, they don’t allow clean identification of kaons. Nevertheless, SIDIS experiments with kaons in the final state are a key ingredient in the understanding of the nucleon structure.

In order to extend the capabilities of CLAS12 to detect kaons in the momentum range from 3 to 8 GeV/c, the Frascati group proposed in 2010 to replace one of the Cherenkov counters with a Ring Imaging Cherenkov (RICH) detector. This project involves other INFN groups (Fe, Roma1/ISS, Ge, Ba) as well as International institutions: besides JLab, also the University of Glasgow (UK), the Gutenberg Universitat of Mainz (Germany), the UTFSM in Valparaiso (Chile), the Argonne Laboratory and the Universities of Duquesne and of Connecticut (USA) and the Kyungpook National University (Korea). After the final approval of the project obtained in 2013, in 2014 most of the R&D activities have been completed and the construction of the detector has been started.

The detector is basically made by a large trapezoidal box containing the aerogel radiator, an array of Multi-Anode Photo Multiplier Tubes (MAPMTs) for the detection of the Cherenkov photons and a mirror system that allows the reduction of the area instrumented with photodetectors to about 1 m$^2$. The MAPMTs and the Front-End readout electronics, based on the MAROC3 chip and made by about 25000 channels, are contained in a panel installed in the lower part of the downstream face of the detector.

The main activities pursued in 2014 are:

- the completion of the studies on the Hamamatsu H8500 MAPMTs, with the publication of the results (Publication 5);
- the purchase of the first two squared meters of aerogel;
- the finalization of the design of the mechanical structure of the detector and the beginning of the tender for its construction;
- the definition of the specifications of the mirror system 3);
- the construction of two large-scale prototypes for the study of the cooling system of Front-End electronics and of its assembly.

5 List of Conference Talks

6 Publications


References
