Few-Body Systems (FB20) manuscript No.
(will be inserted by the editor)

Experimental Program of the Future COMPASS-II Experiment at CERN

Luís Silva
on behalf of the COMPASS Collaboration

Received: date / Accepted: date

Abstract Over the last decade the COMPASS experiment has successfully obtained precise results on nucleon structure and hadron spectroscopy, with statistical errors much lower than previously measured. Recently, the new COMPASS-II program, focused on a study of a more complete nucleon description, was approved by CERN. The goal of the program is to access the nucleon structure beyond collinear approximation, including the quark intrinsic transverse momentum distributions, which are described by the Transverse Momentum Dependent (TMD) Parton Distribution Functions (PDFs) and by Generalised Parton Distributions (GPDs). In this way, the COMPASS collaboration proposes to measure the TMD PDFs, for the first time, via the polarised Drell-Yan process. The results will be complementary to those already obtained in polarised Semi-Inclusive Deep Inelastic Scattering (SIDIS). The GPDs can be accessed using deeply virtual Compton scattering and hard exclusive meson production using an unpolarised hydrogen target in a kinematic region not yet covered by any existing experiment. Also unpolarised SIDIS will be studied, by improving the knowledge of the strange quark PDF and obtaining the kaon fragmentation functions. Another topic covered in this COMPASS-II program is the measurement of the pion and kaon polarisabilities using the Primakoff reaction, which corresponds to a test of the chiral perturbative theory.

Keywords Spin Structure of the Nucleon · Generalised Parton Distributions · Transverse Momentum Dependent PDFs · Pion and Kaon Polarizabilities

PACS 21.45.-v, 13.88.+e, 24.85.+p

Presented at the 20th International IUPAP Conference on Few-Body Problems in Physics, 20 - 25 August, 2012, Fukuoka, Japan

L. Silva
LIP – Laboratório de Instrumentação e Física Experimental de Partículas
Av. Elias Garcia 14 - 1
1000-149 Lisboa
Portugal
Tel.: (+351) 21 799 50 28

E-mail: lsilva@lip.pt

1 Introduction

The COmmon Muon and Proton Apparatus for Structure and Spectroscopy (COMPASS) is a fixed target experiment located in the SPS accelerator, at CERN. It began taking data in 2002. The COMPASS spectrometer is a fifty meter long two-stage spectrometer, containing a Ring Imaging Cherenkov detector, a set of electromagnetic and hadronic calorimeters and a more than three hundred tracking planes. COMPASS has the possibility to have a longitudinally polarised beam and a longitudinally and transversely polarised target [1]. After a decade of successful and precise results on nucleon structure and hadron spectroscopy the COMPASS Collaboration proposed a new physics program [2]. This proposal, approved in December 2010 and started in 2012, is focused on the study of a more complete nucleon description beyond the collinear approximation. A new description including the transverse distance of partons to the nucleon centre of momentum is given by the so-called Generalised Parton Distributions (GPDs). Another different approach regarding the description of the nucleon using the intrinsic transverse momentum of the partons, k_T, is provided by the Transverse Momentum Dependent (TMD) Parton Distribution Functions (PDFs). Also two other subjects will be addressed, the unpolarised PDFs and TMD effects in Semi-Inclusive Deeply Inelastic Scattering (SIDIS) and the pion and kaon polarisabilities.

2 Generalised Parton Distributions

The GPDs provide a new description of the nucleon structure. These functions embody both nucleon electromagnetic form factors and PDFs; the GPDs correlate (transverse) spatial and (longitudinal) momentum degrees of freedom of quarks and gluons, giving thus a 3D picture of the nucleon. There are four GPDs: H^f, E^f, $\widetilde{H}^f$ and $\widetilde{E}^f$, $(f = u, d, s, g)$. The GPDs drew special attention after it was shown that the total angular momentum of a given parton species f is related to the 2^{nd} moment of the sum of the two GPDs H^f and E^f via the Ji relation [3]. This finding was one the major booster to experimental and theoretical activities aiming at determining GPD, since they provide information on quark orbital angular momentum.

The GPDs are accessed by using hard exclusive processes in a broad kinematic range, like Deeply Virtual Compton Scattering (DVCS). There is another process, the so-called Bethe-Heitler (BH) process, which competes with the DVCS (details in Ref. [2]). Both processes interfere as they have identical final states for the channel $\mu p \to \mu p \gamma$.

The DVCS cross section can be parametrised as a function of t, the momentum transferred between initial and final hadron states, the DVCS cross section behaves as a decreasing exponential with slope parameter B. This parameter B can be related to the transverse distance between the struck parton and the nucleon centre of momentum: $B \approx \langle r_\perp^2 \rangle / 2$. Fig. 1 shows the expected statistical precision in B as a function of x_{Bj} assuming 280 days of data taking, together with the existing measurements from ZEUS and H1 experiments. Two scenarios are shown, one considering the presently existing calorimeters, and another where a larger coverage calorimeter ECAL0 is added. As it is shown, the COMPASS-II measurement can improve very significantly the present knowledge of the nucleon transverse dimensions.

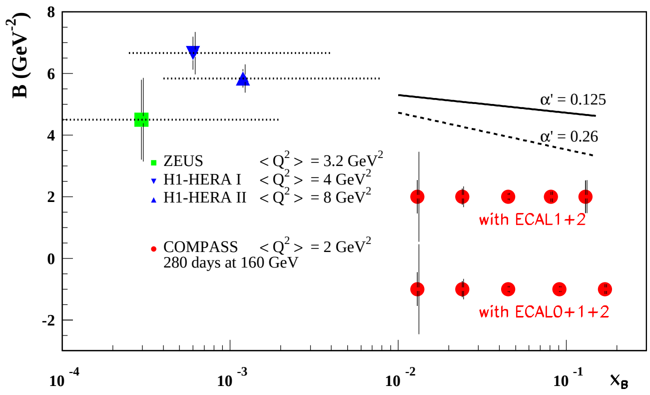

Fig. 1 Projection for measuring the x_{Bj} dependence of the B parameter together with the published results from ZEUS and H1.

3 TMDs

The TMD PDFs provide a new description of the nucleon that includes the transverse intrinsic momentum k_T. There are two ways to access the TMD distributions: one is using the Drell-Yan process in which a quark and an antiquark annihilate producing a lepton pair, the other way to study the TMDs is to use the polarised Semi-Inclusive Deeply Inelastic Scattering (SIDIS) process.

The Drell-Yan (DY) measurement will be done with a π^- beam at 190 GeV/c colliding on proton, a two-cells (NH_3) transversely polarised target will be used. More details about the experimental setup can be found in [2]. A dimuon trigger based on large acceptance hodoscopes will select the interesting events. The like-sign muon pairs sample will be used to estimate the combinatorial background, which is expected to be negligible in the high mass region ($4 \leq M_{\mu\mu} < 9$ GeV/c^2) where we propose to do the main measurement. Polarised DY experiments can study TMD distributions like the so-called Sivers $f_{1T}^{\perp}$ and Boer–Mulders $h_1^{\perp}$ distributions. These distributions are accessed by measuring the azimuthal asymmetries which depend on two azimuthal angles: ϕ_S of the target spin with respect to the transverse momentum of the virtual photon in the target rest frame and ϕ between the incoming hadron and outgoing lepton plane in the Collins–Soper frame (see Ref. [2]), as well as on the Feynman variable $xF = x_\pi - x_p$. Here x_π and x_p are the momentum fractions carried by the involved quarks in the pion and proton, respectively. The theory predicts that these naive TMD distributions obey a restricted universality and change sign when observed in SIDIS and DY, *i.e.* $f_{1T}^{\perp}\Big|_{DY} = -f_{1T}^{\perp}\Big|_{DIS}$ and $h_1^{\perp}\Big|_{DY} = -h_1^{\perp}\Big|_{DIS}$, for the Sivers and the Boer–Mulders functions respectively. The projected $A_T^{\sin\phi_S}$ asymmetry measurement in the high-mass region $4 \leq M_{\mu\mu} < 9$ GeV/c^2, is compared to predictions in Fig. 2. The measurement will certainly be able to answer the sign question of T–odd TMD distributions. There are several DY experiments planned, but COMPASS is the only experiment that will measure for the first time the TMD distributions, in particular the T–odd Sivers and Boer–Mulders functions.

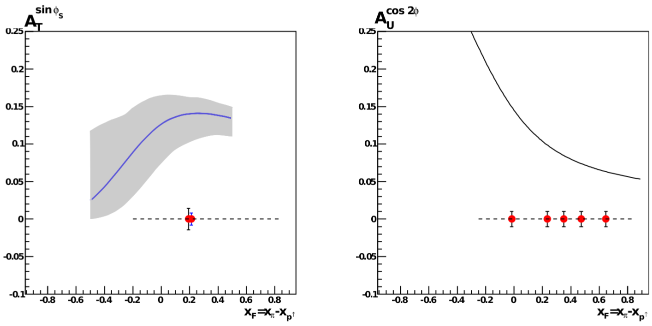

Fig. 2 Theoretical predictions and expected statistical errors for the Sivers asymmetries.

4 Unpolarised SIDIS and Pion and Kaon Polarisabilities

In parallel with the GPD program, further studies of unpolarised SIDIS will be performed. The information about the PDFs inside the nucleon can be accessed by using DIS. By selecting the final state hadron allows us to measure flavour separated PDFs; in particular for the strange quark the uncertainties are still considerably large, in this sense COMPASS-II can give a valuable contribution to constrain the strange quark distribution $s(x)$ in the region of high x ($x > 0.006$). Also the Fragmentation Functions (FFs) can be accessed, in particular the kaon FF. These new data to be collected together with the existing statistics of COMPASS will allow to perform a scanning of the PDFs and FFs as a function of x and z, and consequently also a future NLO global analysis. Pion and kaon polarisabilities will be measured at COMPASS-II, providing a test of the Chiral Perturbation Theory (ChPT) which predicts the strong interaction of the Goldstone bosons (pions and Kaons). The pions and kaons inner structure is revealed by its response to the presence of an electromagnetic field, *i.e.* the Pion and Kaon Polarisabilities. COMPASS will measured these polarisabilities using the so-called Primakoff reaction, $\pi^- Z \to \pi^- Z\gamma$, with the γ being deviated at an angle θ. At leading order of Quantum Chromodynamics (QCD) theory, these polarisabilities are given as the sum of three terms, which depend on the dipole and quadrupole electric and magnetic responses. These dipoles and quadrupoles are accessed by measuring the modulations in θ.

Acknowledgements This work was partially funded by the portuguese Fundação para a Ciência e Tecnologia. The author would like to thank to Fundação Oriente for the financial support which covered partially the travel expenses to attend this conference.

References

1. P. Abbon *et al*: The COMPASS Experiment at CERN. Nucl. Instrum. Meth. A 577 455-518 (2007).
2. F. Gautheron *et al.*: COMPASS-II Proposal. CERN-SPSC-2010-014, SPSC-P-340, CERN, Geneva (2010)
3. Ji, X.-D.: Gauge-Invariant Decomposition of Nucleon Spin. Phys. Rev. Lett. 78, 610-613 (1997).
4. M. Anselmino *et al*: Sivers effect in Drell-Yan processes. Phys. Rev. D 79 054010 (2009).